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ENGINEERS

Electrooptic Recording

Color Internegative

Kinescope Exposure Control

Kinescope Time-Zone Delay

High-Speed Photography in Great Britain

70mm Sequence Camera

Film Editor

Developing Machine

The Stereoscopic Art—A Reprint

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Sound-on-Film Recording Using Electrooptic Crystal Techniques . . .
ROBERT DRESSLER and ALBERT A. CHERNES 205

An Intermediate Positive-Internegative System for Color Motion Picture Photography . . . . . .
C. R. ANDERSON, N. H. GROET, C. A. HORTON and D. M. ZWICK 217

Kinescope Recording Film Exposure Control . . . . . .
RALPH E. LOVELL and ROBERT M. FRASER 226

Time-Zone Delay of Television Programs by Kinescope Recording . . .
RALPH E. LOVELL 235

History and Present Position of High-Speed Photography in Great Britain . . . . . W. DERYCK CHESTERMAN 240

Rapid-Sequence Camera Using 70mm Film . . CHARLES A. HULCHER 247

Precision Film Editor Utilizing Nonintermittent Projection . . . . . .
TORBEN JOHNKE 253

The Bridgamatic Developing Machine . . . . . .
JOSEPH A. TANNEY and EDWARD B. KRAUSE 260

The Stereoscopic Art — A Reprint. . . . . JOHN A. NORLING 268

Reels, Magazines, Spindles for 3-D 309
73d Convention 310
75th Convention 311
1953 Nominations 312
Pacific Coast Section Meeting . . 312
BOOK REVIEWS 313
Filter Design Data for Communication Engineers, by J. H. Mole, reviewed by G. W. Read; *Compt. rendu, Proceedings of 1951 Stockholm Convention of the International Commission on Illumination*, reviewed by W. W. Lozier; *A Television Policy in Education.*
Journals Available and Wanted . 315
New Members 316
Meetings 316
Employment Service 317
New Products 318

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Sound-on-Film Recording Using Electrooptic Crystal Techniques

By ROBERT DRESSLER and ALBERT A. CHESNES

This paper deals with the theoretical and practical aspects of a sound-on-film recorder with no moving parts, utilizing the birefringence properties of certain crystals. The physical properties of various crystals, as well as final performance measurements of the entire sound system, are discussed.

FOR THE PAST ten years, Paramount Pictures has been engaged in the development and production of a theater television and video recording inter-film system. In a system of this type, both the sound and picture must be impressed on the film simultaneously. Conventional modulators used for sound recording are expensive, quite fragile and can easily be rendered inoperative by overvoltage. Since Paramount's inter-film equipment is designed to be operated by lay people for the most part, there came the need for a low-cost, rugged sound modulator.

The light modulator to be described makes use of the physical properties of some materials which allow them to retard polarized light. Before beginning a detailed description of the modulator, it is well to become familiar with the physical phenomena which make light modulation possible.

Presented on October 10, 1952, at the Society's Convention at Washington, D.C., by Robert Dressler, who read the paper, and Albert A. Chesnes, Paramount Pictures Corp., 1501 Broadway, New York 36, N.Y.

General Considerations

If a light source is placed behind crossed polarizers, essentially all light output from this assembly is obscured. Light dips of 300:1 or better are obtained with reasonable polaroids. It has been noticed that a large number of common solid transparent materials, when placed between these polarizers, will produce two rays travelling with different velocity so that the light becomes elliptically polarized and produces a component of energy that will pass through the second polarizer. Cellophane, lucite and polystyrene are just a few of the materials which will produce optical birefringence. There is also a class of liquids which when placed in a *strong electric field* will produce rotation of a polarized beam of light. This effect for liquids was discovered by Kerr and bears his name, the Kerr effect.[1] Kerr cells made with these liquids can and have been used as light modulators. However, several difficulties appear when

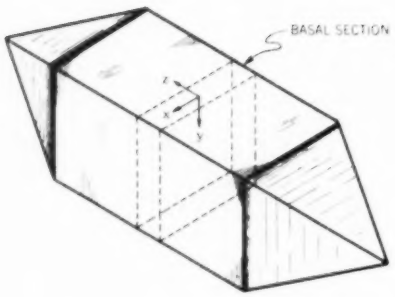

Fig. 1. Typical ADP crystal.

using cells of this type. One important difficulty deals with liquid purity and manifests itself because many of the materials which exhibit a high Kerr effect are deteriorated by the electric field required to produce the effect. It therefore becomes necessary to constantly pump new liquid through the cell to keep it pure, an obvious disadvantage.

Continuing with materials which exhibit optical retardation when placed *in an electric field*, we come to a group of solids studied for the most part by Pöckels, and the effect is known as the Pöckels effect.[2] Examples of some of these materials are quartz, sodium chloride and zinc sulfide crystals. These materials are stable solids and form a suitable group on which light modulation studies can be built. Almost every early experimenter who has worked with the Pöckels effect cites the zinc sulfide crystal as the one with the ideal property for light modulation. To the present time, unfortunately, no zinc sulfide crystals have been synthesized, and pure crystals of usable size are rarely found in nature. So, while the zinc sulfide crystal is the most desirable, it nonetheless becomes necessary to study other crystals, particularly the types which can be easily synthesized in the laboratory. Two such crystals are ammonium dihydrogen phosphate (ADP) and potassium dihydrogen phosphate (KDP). The ADP crystal has many commercial uses

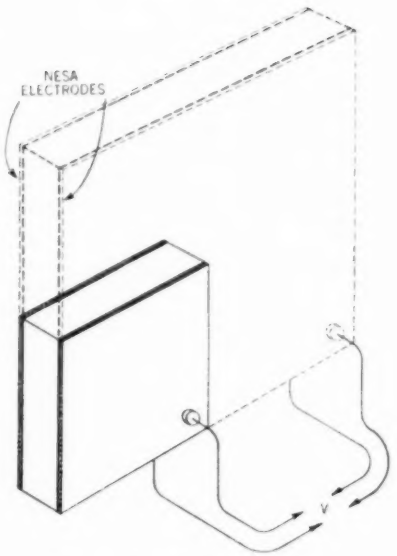

Fig. 2. Application of voltage to crystal structure.

and is comparatively easy to grow. KDP crystals take longer to grow and do not have as many commercial applications, although it will be shown that they do have certain advantages over the ADP for sound modulator applications.

Having stated an intention to use a crystal to produce a desired effect, it is necessary to state which section of the complete crystal will be used, since crystals may have different optical properties for different sections through them. The section of the ADP crystal which displays the property we wish to study is a basal section, or a "Z" cut as it is termed. Figure 1 shows a complete crystal of ADP, and the dotted portion shows the basal section. Another consideration necessary to produce the desired effect is the application of the electric field to the crystal section chosen, or how the crystal shall be submerged in the electric field. For zinc sulfide, the electric field is applied perpendicular to the light beam passing through the crystals.

With ADP, the electric field is placed parallel to the light beam, necessitating transparent electrodes. Nesa glass or a thin coating of chromium or gold makes excellent electrodes. Nesa glass (stannous chloride sprayed on glass), the most light-efficient, is the electrode used in the present modulators.

An interesting property results when the mode of operation is such that the light beam and electric field are parallel; namely, the light retardation depends only on the *potential* across the crystal. This is important since it makes the operating voltage independent of the aperture of the optical system (Fig. 2). With a *transverse* electric field, the wider the aperture, the smaller the electric field in the crystal for a given applied voltage and therefore less retardation. If the electric field is parallel to the light passing through the crystal, the electric field is constant and independent of the aperture. This would seem to indicate that the voltage would depend on the thickness of the crystal. This is not the case, however, since the electric field is halved by doubling the crystal thickness, but the time, or length of path, the light beam is in the crystal is doubled and the two effects cancel. Therefore, the total retardation depends only on the potential placed across the crystal. Apertures of any size can be used and closed with a given potential, in contrast to the extremely high voltage which would be necessary for a Kerr cell with large apertures.

If the crystal thus described is placed between crossed polarizers and the zero potential condition examined, the resulting transmission field, instead of being uniform, shows ellipses of alternate dark and bright sections. This configuration is the last phenomenon that needs investigation in connection with ADP crystals. It is caused by the *angular field* of the beam of light entering the crystal. ADP not only retards the light beam when placed in an electric field, but it has a complex retardation function with incident light angle. That is to say, beams entering at different angles, in general, are retarded by different amounts. Consider the zero potential condition and refer to Fig. 3. The center black portion indicates retardation for light that is normally incident to the crystal. Notice that for zero potential applied, there is no birefringence; therefore, there is a dark spot in the center since only a single ray is passed and the polarizers are crossed. The next light ring on Fig. 3 indicates the locus of rays of all light entering at an angle away from normal incidence. The next dark section indicates a retardation of one ray with respect to the other of 360°. So, while the light areas look alike and dark areas look alike, they nonetheless represent different amounts of relative retardation. It is for this reason that only the region near normal incidence is utilized in the modulator. This is accomplished by placing the crystal structure in a collimated beam. However, the conventional sound track has finite dimensions and it will be impossible therefore to collimate the beam exactly. The effect of having to use a finite angular field will be discussed later.

Transfer Characteristics

With the device thus outlined, the first point of interest is that of the transfer characteristics, that is, a statement on voltage input versus light output. Figure 4 is a summary of the important relationships associated with analytically expressing the transfer characteristics. The function is not linear but it does have a reasonably linear portion. By expanding the transfer function about an arbitrary bias point into a Bessel expansion, it is seen that harmonic distortions will occur due to the nonlinearity of the transducer as the percent modulation is increased. By choosing a proper bias point, the function can be made symmetrical about the bias point, thus causing all even harmonics to vanish. Figure

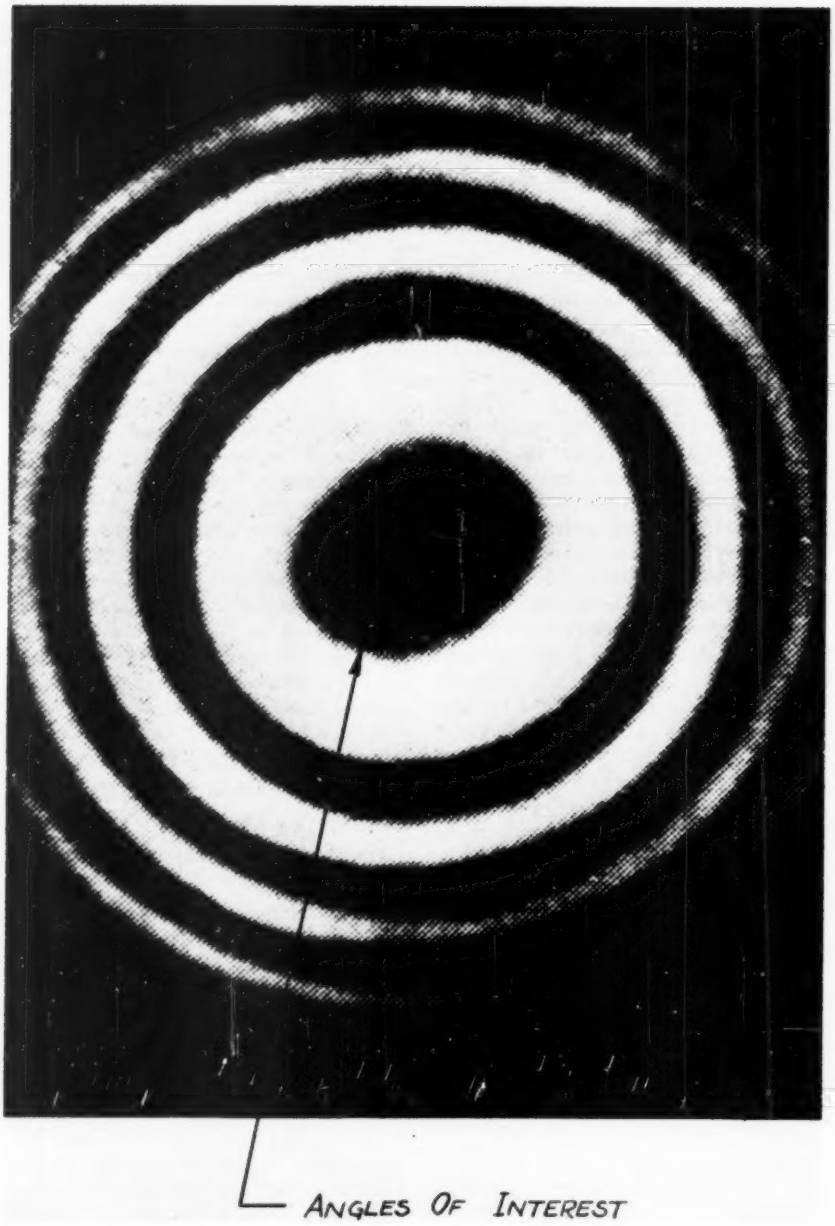

Fig. 3. Transmission field of crystal between cross polarizers with zero potential.

Intensity Transmitted:

$$\frac{I}{I_0} = \cos^2 \pi t$$

where t = retardation in waves.

For an arbitrary bias point and sinusoidal modulation:

$$\frac{I}{I_0} = \frac{1}{2} + \frac{1}{2}[\cos \theta_0 \cos(\theta_S \sin \omega t) - \sin \theta_0 \sin(\theta_S \sin \omega t)]$$

where $\theta_S = 2\pi$ (retardation caused by modulated signal),
and $\theta_0 = 2\pi$ (retardation caused by the bias plate).

Expanding in a Bessel Series:

$$\frac{I}{I_0} = \frac{1}{2} + \cos \theta_0 \left[\frac{1}{2} J_0(\theta_S) + J_2(\theta_S) \cos 2\omega t + J_4(\theta_S) \cos 4\omega t + \ldots\right]$$

$$- \sin \theta_0 [J_1(\theta_S) \sin \omega t + J_3(\theta_S) \sin 3\omega t + \ldots]$$

choose the bias plate $\theta_0 = \pi/2$
$\therefore \cos \theta_0 = 0$ and all even harmonics vanish.

Fig. 4. Transfer characteristic relationships.

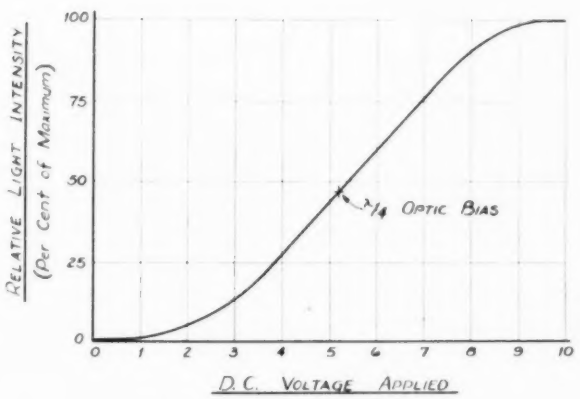

Fig. 5. Transfer characteristic.

5 shows a plot of the transfer characteristics with a proper bias point. This point is labelled optical bias since it is not obtained by d-c biasing the crystal, but rather by inserting a mica quarter-wave plate between the polarizer and crystal. Substitution in these relationships indicates that for 74% modulation, the second harmonic distortion is zero, and the third harmonic distortion is approximately 2.2% of the fundamental component. As the percentage modulation is increased, this figure rises rapidly, and thus the nominal modulation level for proper light valve operation is 75%. Of course, nonlinear electrical amplifiers may be included in the sound system allowing higher percentage modulation.

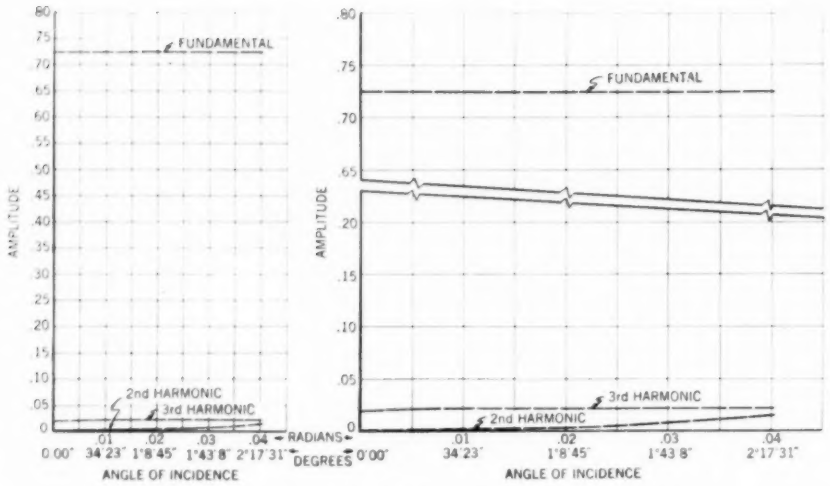

Fig. 6. Effects of angular field; crystal thickness, 0.045 in.

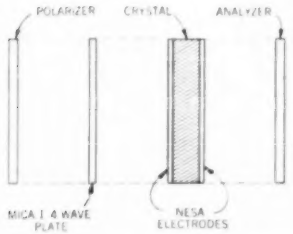

Fig. 7. Diagram of laminated structure.

However, this technique has proven unnecessary, since the 75% level is sufficient for most needs.

Angular Field

The standard modulator slit has a relatively large dimension in one direction, i.e., 0.1 in. Since this slit is the virtual light source for the modulator, all the light passing through the crystal cannot be normally incident. This angular field problem may be overcome by adjusting the length of the optical system and in that manner control the angular field. Figure 6 summarizes how the angular field affects distortion. For zero angular field and 74% modulation, the second harmonic distortion is zero; the third harmonic distortion is approximately 2.2% of the fundamental as noted earlier. As the angular field is increased, the third harmonic distortion remains substantially constant while the second harmonic distortion increases parabolically so that at 2.28° for the half angle, the total distortion from all sources is approximately 3.3%. To keep the modulator slit to the above-mentioned angular field, the overall modulator length is approximately 5 in.

Frequency Response

Before investigating the frequency response of a crystal modulator, it is well to study the laminated crystal structure as it is used. This is necessary since the laminar structure affects the frequency response. The term laminar structure is used since the polarizers, mica quarter-wave plate and crystal, with its electrodes, are all cemented together. This entire assembly is then mounted in a bakelite block. A schematic diagram of this laminar structure is shown in Fig. 7. Figure 8 shows a picture of this structure with a handling arm for fitting

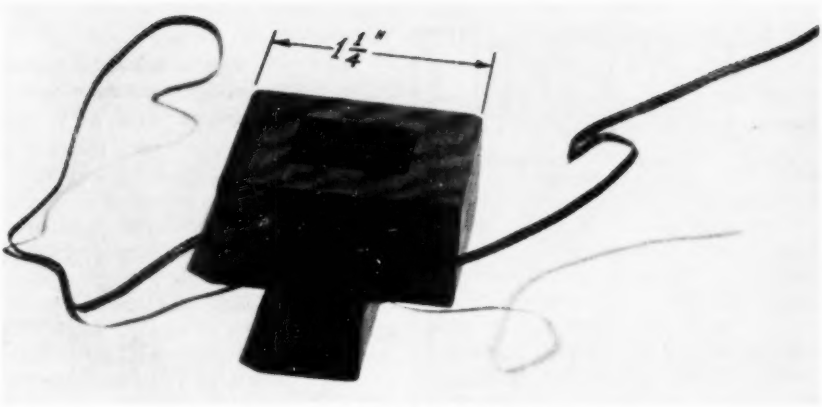

Fig. 8. Complete laminated structure.

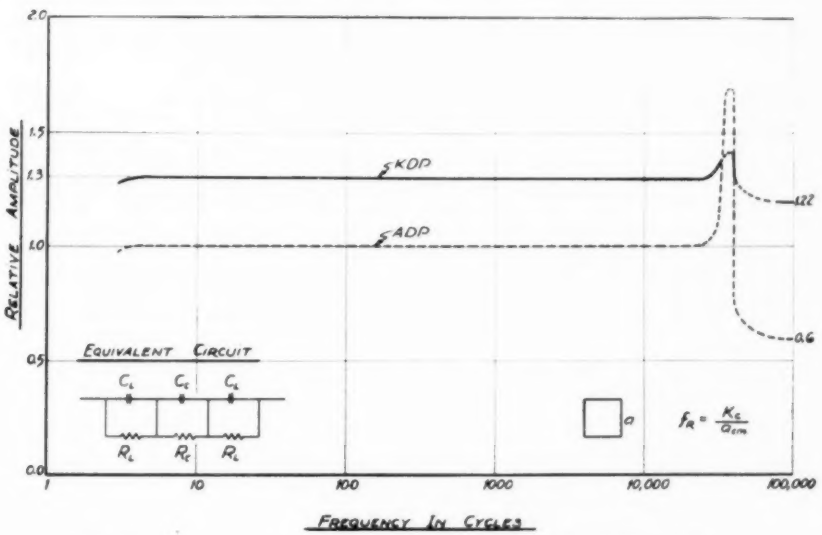

Fig. 9. Frequency response of laminated ADP and KDP crystals.

the laminar structure into the optical system. The frequency response for the ADP structure and its equivalent circuit diagram for the frequency region used for sound modulation are shown in Fig. 9. The structure does not respond to d-c since the crystal electrodes are cemented to the crystal, forming a capacitor resistance network (note equivalent circuit diagram). The d-c terminal resistance is approximately 300 megohms while the terminal capacity is approximately 64 $\mu\mu$f (micromicrofarads). The series capacity made up by the electrode cemented to the crystal is quite large; therefore, the series impedance of these capacitors becomes negligible quite rapidly. As

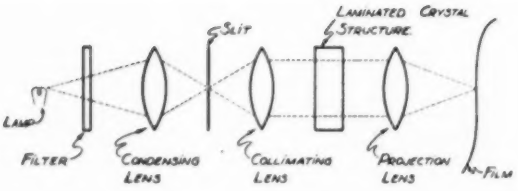

Fig. 10. Schematic layout of light modulator optical system.

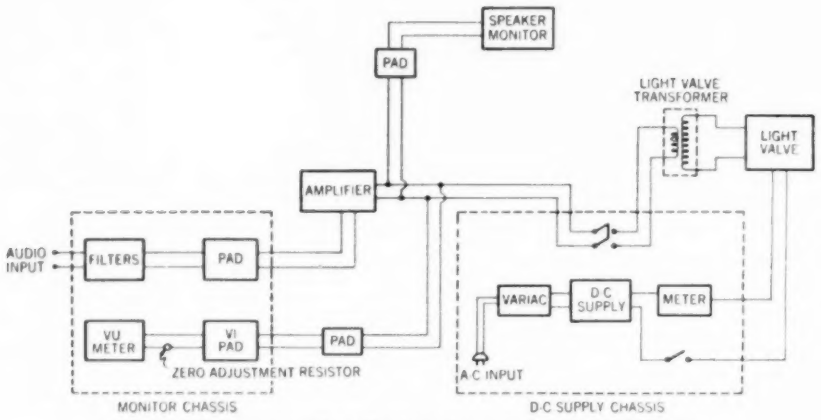

Fig. 11. Interconnection diagram for complete audio system.

indicated by the response curve, mid-frequency gain is attained from approximately 3 cycles/sec until the first Piezo resonance, which in our instance is approximately 40 kc. This resonant point depends upon the physical size of the crystal, in particular upon the length of the sides of the crystal face. The frequency relationship is shown in the figure where $\mathbf{K}_e$ for ADP is approximately 110 kilocycle-centimeters. This constant varies slightly for the KDP crystal. Beyond the resonant peak, whose height incidentally depends upon the mechanical damping of the crystal, the sensitivity falls to about 0.6 of its original flat-region amplitude. The transition from one level to the next has been omitted from Fig. 9. It is not a smooth curve as shown in that figure. After transition, the response remains substantially flat until the next resonance which is a molecular resonance at extremely high frequencies. There have been crystals constructed where added mechanical damping has completely depressed the resonant peak shown on the curve. Thus, a more uniform transition from one amplitude region to the other is obtained. These crystals, with proper electrodes, can be operated well into the megacycle regions.

Figure 9 also shows a comparison of ADP and KDP. The frequency characteristics are very similar. Notice that the KDP is more sensitive (requires 30% less drive) to applied voltage than the ADP crystal. Also, the resonant peaks are not as pronounced for the same damping and further, the amplitudes after transition are very similar.

Physical Description

Figure 10 is a schematic representation for the layout of the optics of the sound modulator. A tungsten filament lamp was chosen as the light source since gas and arc lamps generate in their light

beam a certain amount of noise which is undesirable. Between the tungsten coil and the first optic, a blue filter is placed. This filter serves two purposes. The first is to limit the wavelength which will pass through the crystal structure. This is done since retardation is a function of wavelength. Second, the filter acts as a heat-absorbing filter. Fortunately, both of these requirements contribute only second-order effects to the output, and with no filter the increase in distortion is quite slight. However, since there is ample light available for our application, a blue filter has been included. The wavelength to be transmitted was determined by the spectral response of the motion picture film used.

The lamp filament, which is of the tight-coil variety, is imaged slightly oversized and out of focus on a slit whose dimensions are 0.1 in. × 0.0006 in. The filament image is run slightly out of focus to give a more uniform light distribution across the slit since the coils of the filament, even though they are wound quite closely, give some illumination variation. The slit now becomes the light source and the next optic picks up this aperture and collimates the light beam for passage through the crystal structure. The laminar structure including the crystal has already been described. The placement of the slit pickup optic just mentioned is such that the angular field requirement is met. The final optic or projection optic gathers the collimated beam from the crystal and focuses the image of the slit onto the film. This optic is adjustable so that the image may be sharply focused on the film for different film distances. The magnification of the optical system is unity and therefore the modulation slit height remains 0.0006 in. high. This allows 9,000 to 10,000 cycles to be impressed on the motion picture film without amplitude loss when it travels at 90 fpm. The light transmission efficiency of the entire modulator is 16%.

Electrical Requirements

It was pointed out in an earlier section that the magnitude of the voltage for a given retardation is a function of wavelength. Since a filter has been inserted between the tungsten lamp and the crystal, the wavelength of the transmitted light is known. For 4500 A the required voltage is 7.4 kv per half-wave of retardation. The retardation required for 75% modulation is something less than a quarter-wave and requires between 1600 and 1800 v rms drive. It is interesting to note for zinc sulfide the driving potential is approximately 500 v.

The electrical drive requirements for the ADP crystal structure can be determined from the driving point impedance of the structure. The driving point impedance of these crystal structures is capacitive, and has a dissipation factor of approximately 0.07 which is substantially constant to 50 kc. The capacity measured at the crystal terminals is 64 $\mu\mu$f and is also substantially constant with frequency. The slight variations from a constant as a function frequency of these factors does not affect the design of the driving system and does not affect sound quality. The amplifier used to drive the modulator is a 50-w high-quality amplifier working into a special output transformer designed to drive this load over the frequency range desired. This design was accomplished, giving an overall system response essentially uniform from 30 cycles to 10,000 cycles.

Studies at this laboratory indicate that frequency components above 8500 cycles are very often distorted during film processing and, in addition, many theaters have equipment which would only serve to distort frequency components above this figure. As a result, a wave filter is included in the electrical system to limit the nominal frequency passband from 75 cycles to 8500 cycles. The low end has been attenuated to filter out hum which may exist in some

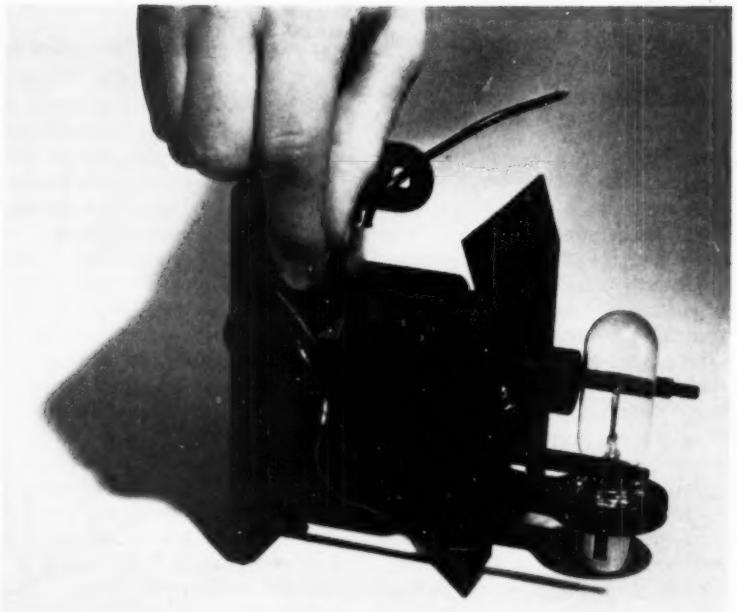

Fig. 12. Completed modulator with cover removed.

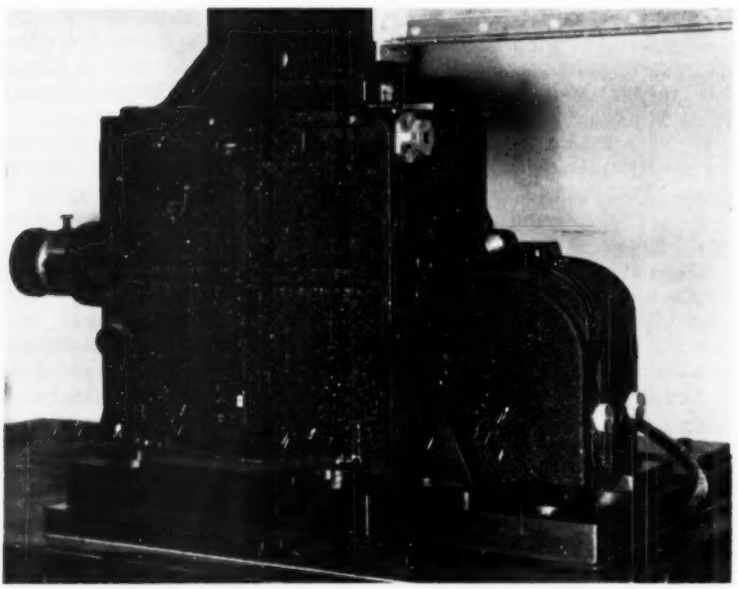

Fig. 13. Modulator mounted on 35mm camera.

installations. If hum and the theater reproducing system do not cause low-frequency distortion, the low-frequency filter may be removed. A diagram of the electrical system is shown in Figure 11. It indicates the required modulation equipment as well as the auxiliary equipment such as VI meters and calibrated attenuators.

The lamp power supply is a variable d-c supply, feeding a 10-v $7\frac{1}{2}$-amp lamp. With the 16% light efficiency figure, the lamp is run at 6 amp for positive recording and 6.8 amp for negative recording. Both levels are well below the nominal lamp rating. These values were determined from standard intermodulation tests for various chemical baths.

Summary

The modulator described records sound on film at 75% modulation with a standard sound-modulation slit, and a total system distortion of approximately 3.3%. The required driving voltage is 2000 v rms derived from a standard audio amplifier through a suitable matching transformer. The frequency response of the entire system is substantially flat from 30 cycles to 10,000 cycles (i.e., within a quarter decibel). The entire modulator is extremely rugged and cannot be damaged by overvoltage. From an operations point of view, it's adjustment is exactly the same as the standard modulators now commercially employed for sound-on-film recording.

A completed modulator with the cover removed is shown in Fig. 12. This figure shows the laminated structure being inserted into its proper position in the optical system. These crystals are interchangeable and can be changed in approximately five minutes. There are no figures available as to the life of these structures since none has failed to this date. One in New York City has been in constant operation since August 1950 and has been used over that period to record sound for approximately 2700 hr. These crystals are stable solids and should have a life measured in tens of years. The crystal structure is held in place by spring clasps and can occupy only one position in the optical system. The tungsten lamp is mounted in a prefocus socket so that interchanging the lamp requires no adjustment of the optical system. Figure 13 shows the modulator mounted on the 35mm camera. The hole under the mounting is for a small fan which cools the entire housing to prevent crystal overheating and increase the lamp life.

Acknowledgments

The authors gratefully acknowledge the helpful suggestion of the Baird Associates Co., and in particular, the suggestions and criticisms of Robert Carpenter of that company.

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Discussion

John G. Frayne (Westrex Corp., and Chairman of the Session): Is there any problem in the application of bias for noise reduction purposes?

Mr. Dressler: This modulator will not work with conventional noise-reduction equipment but noise reduction is possible with special equipment designed for the crystal characteristics. No noise reduction is included with this system at the present time.

Dr. Frayne: What is the signal-to-noise ratio on the film with this device?

Mr. Dressler: I would guess in the neighborhood of 25 to 30 decibels.

George Lewin (Signal Corps Photographic Center): Can you take a picture of a subject through this device and use this principle as an instantaneous shutter.

Mr. Dressler: I think scientifically the answer is yes. In fact, pictures have been taken using crystals of this type. The problem, however, is the narrow angular field. The crystals we are using now are 35 mils thick — this gives a 5° angular field of view. In photographic work, a wider field of view is generally required. This crystal is suited for use as a shutter with optical systems where you can control the light path so as to work with a nearly collimated light beam. When using a crystal of this type for photography, the object to be photographed is put a long way off so as to restrict the angular field. In general, the structure as we have it here is not suitable for picture taking.

An Intermediate Positive-Internegative System for Color Motion Picture Photography

By C. R. ANDERSON, N. H. GROET, C. A. HORTON and D. M. ZWICK

A color printing system for motion pictures is outlined employing: Eastman Color Negative Safety Film, Type 5247; Eastman Separation Panchromatic Safety Film, Type 5216; Eastman Color Internegative Safety Film, Type 5243; and Eastman Color Print Safety Film, Type 5381. The sensitometric characteristics of the two intermediate materials are described. Some methods of using them and the problems involved in color registration printing are discussed.

IN THE PRODUCTION of motion pictures in color, it is necessary, as in black-and-white work, to introduce special effects for dramatic emphasis or enhancement of the mood of the story. It is also convenient to be able to correct portions of the original negative footage for contrast, density or color balance because of unavoidable or accidental variations which may have occurred either in exposing or processing the original film. To accomplish these results it is convenient to use duplicating steps which yield a color internegative whose color characteristics are such that it may be intercut with the original color negative. Such a sequence of steps is shown schematically in Fig. 1. The original camera negative may be printed directly to give a release print, or it may be printed through the separation positives and internegative to a release print. The first method is a rapid way of printing "dailies"; the second procedure gives an opportunity to introduce effects or adjustments in the final print.

Such a duplicating system might be expected to consist of a color negative film, a color duplicating positive material, a color duplicating internegative, and a color release print film. This would follow the familiar practice in black-and-white work. Such a system has, at present, two practical disadvantages. First, it would leave the producer's investment in production costs in dye images whose permanence or resistance to fading has not yet been proved. Second, the quality which can be obtained, at the present time, using four generations of color pictures, is not up to that which is obtained with the system illustrated in Fig. 1.

Communication No. 1524 from the Kodak Research Laboratories, by C. R. Anderson, N. H. Groet, C. A. Horton and D. M. Zwick, Kodak Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y. The paper was presented on October 18, 1951, at the Society's Convention at Hollywood, Calif.

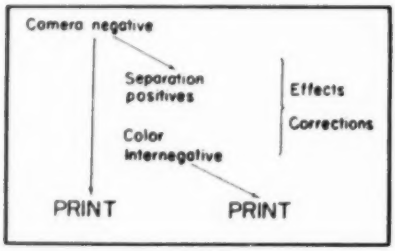

Fig. 1. Sequence of steps involved in making color prints from a color negative.

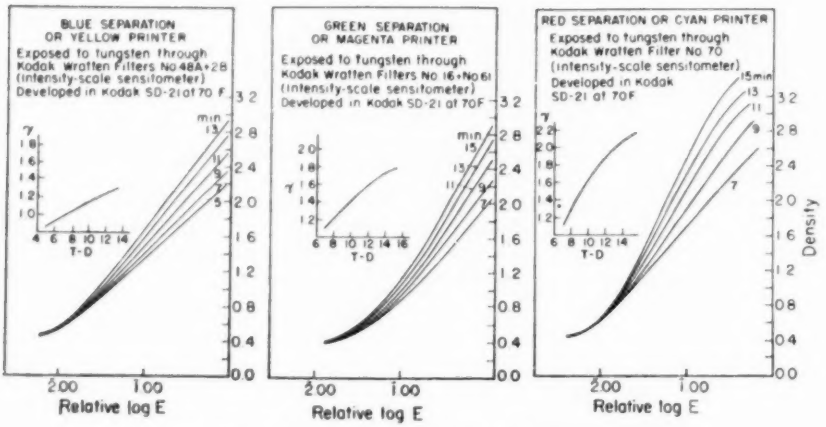
BLUE SEPARATION OR YELLOW PRINTER
Exposed to tungsten through Kodak Wratten Filters No 48A+2B (intensity-scale sensitometer)
Developed in Kodak SD-21 at 70 F
GREEN SEPARATION OR MAGENTA PRINTER
Exposed to tungsten through Kodak Wratten Filters No 16+No 61 (intensity-scale sensitometer)
Developed in Kodak SD-21 at 70F
RED SEPARATION OR CYAN PRINTER
Exposed to tungsten through Kodak Wratten Filter No 70 (intensity-scale sensitometer)
Developed in Kodak SD-21 at 70F
T-D
Relative log E
Density

Fig. 2. Families of characteristic curves of Eastman Separation Panchromatic Safety Film, Type 5216.

The color system described in this paper is based on the use of four photographic materials, three of these yielding dye images, one of them yielding silver images. These are: Eastman Color Negative, Type 5247; Eastman Separation Panchromatic Film, Type 5216; Eastman Color Internegative Safety Film, Type 5243; and Eastman Color Print Safety Film, Type 5381. The first and last of these films have been described previously.* It is the purpose of this paper to discuss briefly the characteristics and properties of the two intermediate films just named and to outline the method of using them.

Eastman Separation Panchromatic Film, Type 5216, is a black-and-white material, the sensitometric characteristics of which are shown in Fig. 2. The three sets of curves are time of development series for red, green and blue exposures. It will be noted that the contrast range is intermediate between that of the usual negative and positive materials in black-and-white. The emulsion is slower but gives sharper pictures than the usual panchromatic duplicating films. It may be processed in any standard black-and-white motion picture negative developer, the contrast being controlled by time of development, as shown in the curves. Figure 3 shows a wedge spectrogram printed below one on Eastman Fine Grain Duplicating Negative, Type 5203. The sensitizing of

* W. T. Hanson, Jr., "Color negative and color positive film for motion picture use," *Jour. SMPTE*, 58: 223–238, Mar. 1952.

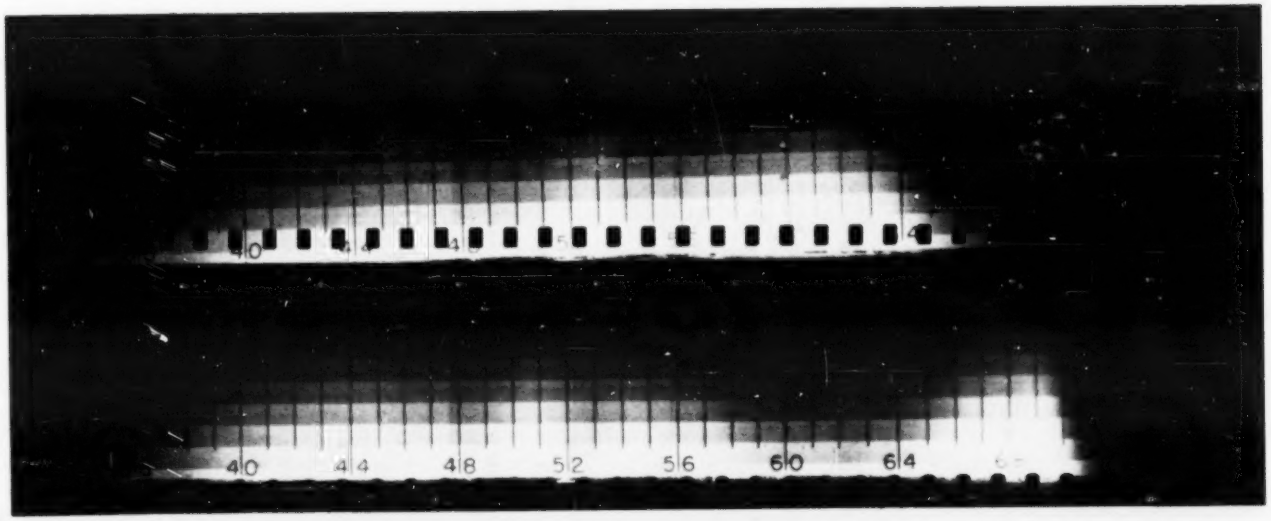

Fig. 3. Spectrograms of Eastman Fine Grain Duplicating Negative, Type 5203 (above); and Eastman Separation Panchromatic Safety Film, Type 5216 (below).

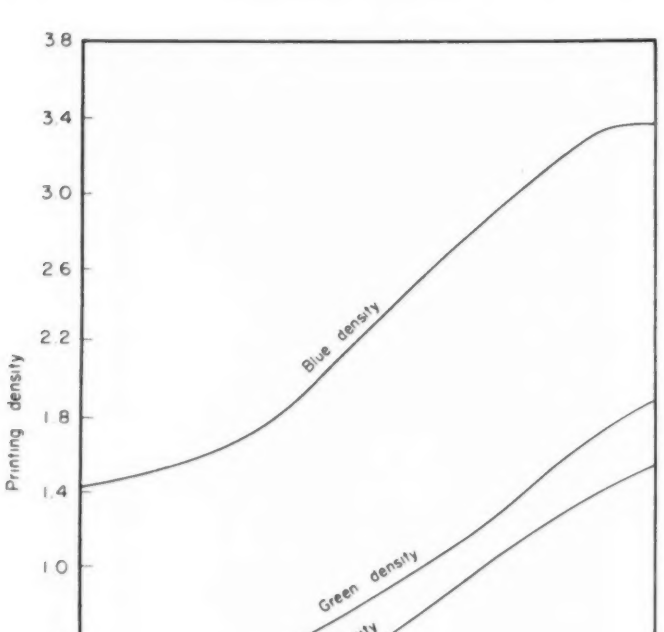

Fig. 4. Characteristic curves of Eastman Color Internegative Safety Film, Type 5243; red, green and blue printing density versus relative log exposure.

this new film extends to longer wavelengths in the red region of the spectrum than that in the older material. This is to bring the maximum sensitivity close to the peak absorption of the cyan dye in the color negative, thus giving maximum contrast and color separation for any specified time of development. The present film contains a dye in the emulsion which is not fully removed during processing. This dye imparts a slight greenish tint to the processed film.

The internegative film, Eastman Color Internegative Safety Film, Type 5243, contains the same color formers and has the same density range as Eastman Color Negative Film, Type 5247. The speed, graininess and sensitization are quite different. Figure 4 shows the sensitometric characteristics of this film. The minimum densities of the blue and green are higher than that of the red, owing to the presence of the colored couplers. The contrast is higher than that of the negative film, Type 5247.

In this film, the magenta coupler is in the top, b'ue-sensitive layer, so that the blue exposure leads to magenta dye. The green exposure results in the formation of cyan dye, and the red exposure gives yellow dye. These noncomplementary relations between sensitizer and dye image are used in order to profit from two

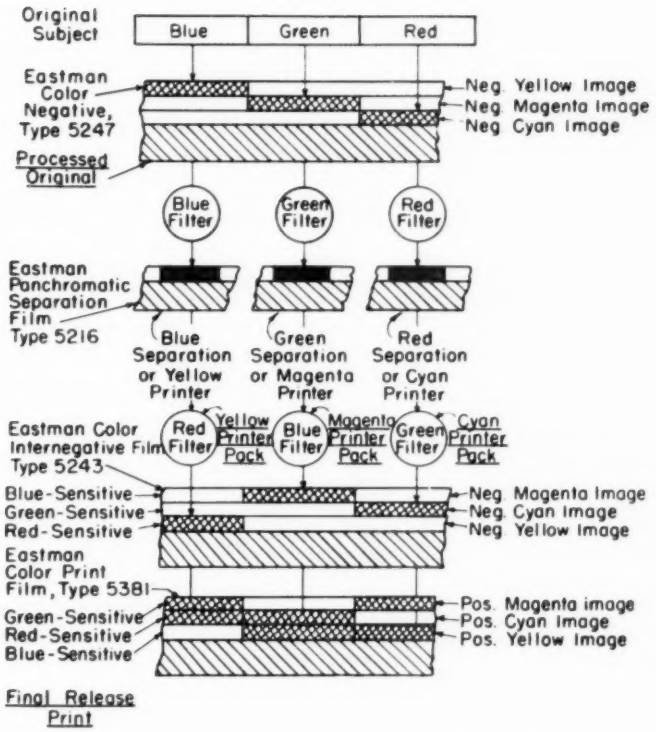

Fig. 5. Schematic diagram showing relation of film sensitivity to dye formation through complete printing stages from color negative to the final release print.

observed facts: (1) that the magenta dye image in a color film determines, to a large degree, the sharpness of the picture; and (2) that the top layer of a multilayer film, in general, gives better picture sharpness than the lower layers. Of course, such relationships between color sensitivities and dye formation, if used in a camera film which was printed on a color film with normal sensitizing, would yield a false-color system quite useless for visual purposes. Because the three records of the separation positives are printed separately on the internegative, this condition is avoided.

The internegative contains colored couplers, similar to those in Eastman Color Negative, which provide automatic masking to correct in part for the unwanted absorptions of the cyan and magenta dyes of the negative image. Thus, the duplicating stage does not introduce the brightness changes and hue shifts which would occur in the absence of this masking.

Processing of the internegative is carried out in the same solutions and with the same precautions as Eastman Color Negative, though at reduced time of development.

Figure 5 is a schematic diagram of the relations of sensitivity to dye formation in the complete printing system from the color negative to the release print. At the top of the figure the red, green and blue represent the amounts of

these colors reflected from the original subject. These colors expose the camera film, forming the negative image in cyan, magenta and yellow dye, respectively. From the color negative three separation positives are prepared on Eastman Separation Panchromatic Safety Film. These positives are exposed through red, green and blue filters, giving a permanent silver record of each of the three dye images. It is now possible to print these records in the correct dyes of the internegative film. This is shown in the lower portion of the diagram where the sensitivities appear on the left, the dyes formed on the right. Since it is necessary that the record of the dye images of the negative become finally the corresponding dye images of the internegative, it is obvious from the figure that the red-separation positive must be printed with green light. Similarly, the magenta dye in the blue-sensitive layer requires the green separation positive to be printed with blue light, and the third, or blue, separation must be printed with red light. Thus, the original dye images of the negative will appear in the same dyes in the internegative and will give a print with normal color reproduction.

In order to achieve proper tone reproduction in printing the color internegative from the three separation positives, it is necessary to adjust the exposure so that the straight-line portion of the sensitometric curve of the color internegative is used. Underexposure at this stage causes loss of contrast in the shadows, as observed in the final print. Overexposure produces an internegative that may be too dense to print and may lead to low contrast in the highlight areas.

The last stage in Fig. 5 shows the printing of the internegative on Eastman Color Print Film. This stage of printing may be done with white light modified as may be found necessary by Kodak Color Compensating Filters, or single or multiple light-source printers may be employed in which red, green and blue light are appropriately mixed at the printing aperture.

We may turn now to a more specific study of these operations and to the precautions which must be observed. Because of the presence of the dye masks in the original negative, the choice of filters in making the separations is critical. The set of filters recommended for making these separations is:

Separation Positive	*Kodak Wratten Filter No.*
Red	70
Green	16 + 61
Blue	48A + 2B

These filters have been chosen to give the highest contrast and the most satisfactory color separation from the masked-dye negative images.

There are fewer restrictions on the choice of filters to be used when printing the separation positives on the internegative. Because the printing at this stage is from silver images, no effect is produced on the contrast or color reproduction by changing the transmissions of the filters unless the transmissions are made so broad that the filters transmit in an adjoining region of the spectrum. For example, the total transmission of the green filter must not be so broad that it exposes either the red- or blue-sensitive layer of the internegative film. The recommended filters have been chosen in this case to match the peak sensitivities of the internegative film as follows:

	Kodak Wratten Filter No.
Yellow printer or blue separation	29
Magenta printer or green separation	34 + 38A
Cyan printer or red separation	16 + 61

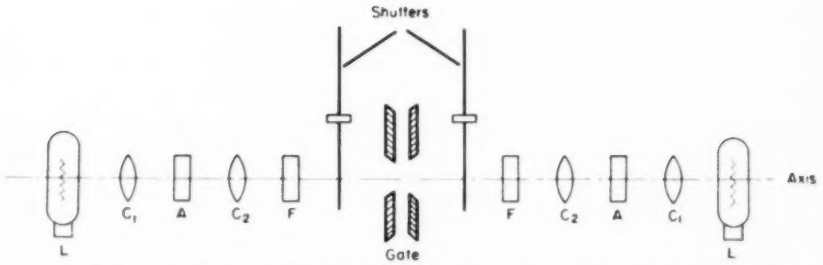

Fig. 6. Schematic diagram of a two-lamp step-contact printer, of a type suitable for maintaining registration through two steps of printing without the necessity of changing registration pins: L = lamps; C_1, C_2 = condenser lenses; A = heat-absorbing glass; F = filterholders.

In order to produce a satisfactory final print with the color images in registration, two requirements in printing equipment must be met.

1. Provision must be made for maintaining registration and correct orientation during the printing of the separation positives from the original negative and during the printing of the internegative from the separation positives.

2. Provision must be made for color timing. If an entire picture is to be printed from an internegative, it is likely that proper timing during the printing of the separation positives and internegative will result in an internegative from which the final release prints can be made at one printer light setting. However, if the final print is made from an intercut original and internegative, the printer used in making the final print will require color-timing equipment. Furthermore, the internegatives will require slightly different intensity timing since an internegative will be of somewhat greater density than the corresponding original negative. This may require an increase in printer intensity of several printer points.

Because of the diversity of printing equipment it is impossible to give specific rules for every kind of printer, but some general suggestions may be useful. To maintain accurate registration it is essential that the full pin of the registering printer enter the same perforation relative to the frame, both in making the separation positives and in printing these on the internegative. This may be achieved by using a step-contact printer with registration pins and two light sources, one on each side of the gate, as shown schematically in Fig. 6. In this figure, symmetrically placed on each side of the gate, are shown the lamps, L, the condenser lenses, C_1 and C_2, the heat-absorbing glasses, A, and the filterholders, F. In making the separations from the camera original, the lamp on one side is used. In printing the separations on the internegative, the lamp on the other side is used. In this way it is unnecessary to turn the separation positives over to maintain emulsion-to-emulsion contact in printing. Another way of accomplishing the same result with a single light source is to have removable pins in the printing gate so that they may be changed to the correct position for the second operation. In the design of any registering printer it is desirable to have the full pin fill the same perforation as was used by the camera. This is not essential to registration when printing from an integral-tripack original but it improves screen steadiness.

In such a step-contact printer, picture sharpness is improved if a partial vacuum is maintained between the two

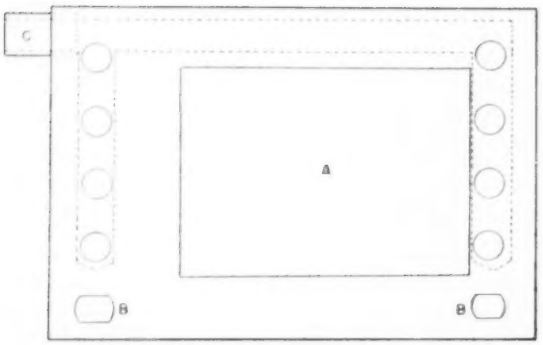

Fig. 7. Diagram of a contact printing gate utilizing a partial vacuum for improved picture sharpness: A = printing aperture; B = registration pins; C = channel to vacuum pump.

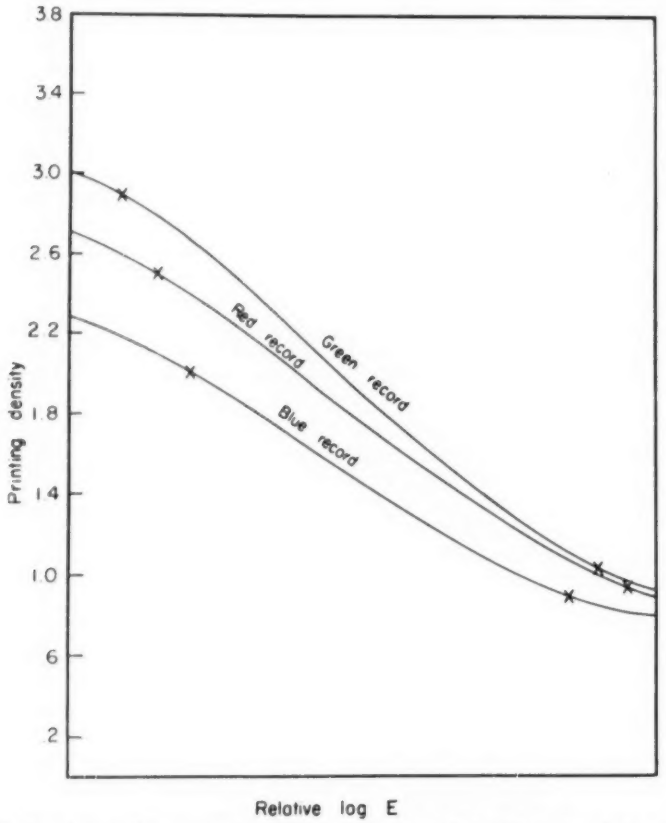

Fig. 8. Sensitometric curve of print from Eastman Color Negative Safety Film, Type 5247, as a neutral sensitometric scale on Eastman Separation Panchromatic Safety Film, Type 5216.

films during the exposing part of the printing cycle. Figure 7 shows a front view of the contact printer gate, where A is the exposing aperture and B are the registration pins. Any air trapped between the two films is drawn out from holes matching the perforations by a vacuum pump attached at C through the channel, shown in dotted lines.

If an optical printer is used for both steps, the same requirements must be satisfied regarding registration and may be achieved by the same means. If the separations are made on a step-contact printer and the internegative is printed on an optical printer, or vice versa, the location of the registration pins in both printers must be arranged to permit the maintenance of registration and orientation for projection. In any optical printing step, the resulting contrast will be dependent on the Callier Q-factor of the original. This is particularly true when printing from the separation positives because the silver image scatters far more light than a dye image does. This means, of course, that if separations have been made at the correct contrast for optical printing on the internegative they will give too low a contrast for a satisfactory contact print.

In making certain types of effects using the present films, it must be kept in mind that the gammas of the three separation positives are not equal, since the unequal process gammas of the color internegative are compensated for in these positives. This is illustrated in Fig. 8, which shows the "print-through" sensitometric curves for a color negative neutral scale exposure printed on the separation positive film. The ×'s on the curves mark the densities of the whites and shadows occurring in a typical scene. The density ranges in the three separations are not equal. If a fade or dissolve is made by printing such positives on the internegative film, these density ranges must be spread over the same number of frames, or a shift in color balance will occur. Consequently, the shutter, diaphragm or other mechanism must be actuated at different rates for the different separations. In cases where the effects can be introduced in making the positives, this difficulty is avoided because the original has matched gammas.

Kinescope Recording Film Exposure Control

By RALPH E. LOVELL and ROBERT M. FRASER

Various devices have been perfected to control accurately the exposure of video pictures to be recorded on motion picture film. These devices, combined with sensitometric control, take much of the guesswork out of the kinescope recording process.

MUCH HAS BEEN WRITTEN about the various phases of recording television images on motion picture film. Equipment has been described, characteristic curves of the various components have been examined, and questions of resolution have been discussed. Little material is available, however, about the methods by which proper film exposure can be obtained from a kinescope tube.

It is the purpose of this paper to describe a practical operating procedure for obtaining optimum film exposure on kinescope recording negatives. This is a technique involving the use of some instruments well known in connection with electronic applications as well as others designed specifically for the purpose.

One of the many handicaps under which the technician worked in the early days of video recording was the lack of suitable instruments for determining conditions of film exposure. The early commercial kinephoto monitors had, as their sole instrument for determining the effects of changes in contrast, brightness and high voltage, a single 50-μa meter, which by selective switching was supposed to indicate conditions in various circuits. The only method of judging maximum exposure conditions with this apparatus was to observe the average cathode current of the 5WP11 recording kinescope. A rough approximation of minimum exposure conditions — referred to as black level — could be obtained by an indication of the grid bias voltage of the 5WP11 kinescope. With this crude method of instrumentation the technician was supposed to maintain uniform exposure and produce good photographic results. Needless to say, this was an almost impossible task.

The situation today at NBC is quite different. Several instruments have

Presented on October 7, 1952, at the Society's Convention at Washington, D.C., by Ralph E. Lovell, National Broadcasting Co., Sunset and Vine, Hollywood 28, Calif., who read the paper, and Robert M. Fraser, National Broadcasting Co., 30 Rockefeller Plaza, New York 20, N.Y.

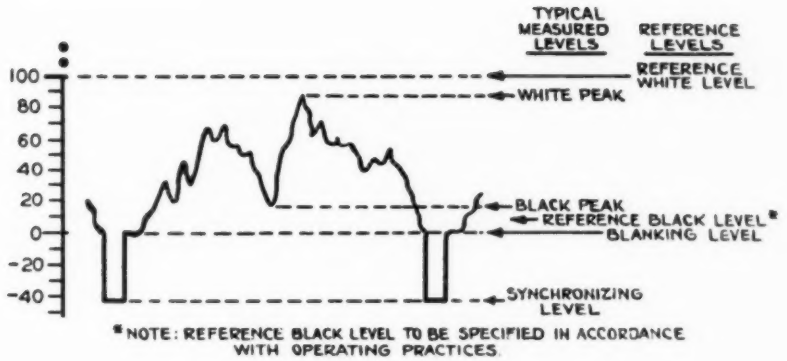

Fig. 1. Television level measurements.

been designed or adapted for this particular purpose which have made exposure control a practical reality.

Nomenclature

Before describing these instruments a few of the terms used in television nomenclature may be briefly reviewed (Fig. 1).* Current television engineering practice is to produce a composite video signal having a peak-to-peak amplitude of 1.4 v. The reference zero for a composite signal is at blanking level, as shown at the left of Fig. 1. The synchronizing pulse is required to have an amplitude of 0.4 v or 40 units in a negative direction from the reference zero. Picture information is contained in the 100-unit portion above reference zero, having a maximum of 1.0 v. Thus peak whites represent 1.0 v above zero with black picture information — commonly referred to as black level — falling about 10 units or 0.1 v above zero.

Exposure Control Equipment

Since 1.4-v peak-to-peak amplitude has been adopted as standard for video signals it is essential that some reliable source be available with which to calibrate monitors and oscilloscopes throughout the television plant. One such source is a peak-to-peak reading voltmeter which is connected across the output of a step-down 60-cycle transformer and potentiometer. By carefully adjusting this meter to read 1.4 v and by applying this voltage to the "calibrate" position on all monitors in the television plant it becomes possible to obtain identical levels from the various studios. A uniform calibrating voltage, such as this, is of extreme importance in kinescope recording and forms the basis for all accurate measurement.

The most important single instrument for controlling exposure is the step generator (Fig. 2), a tool which possesses great value and versatility. This is an electronic signal generator designed and built by NBC principally for kinescope recording, although it is useful in other parts of the television plant and particularly, in this instance, for the stepping of the video signal level. When horizontal-drive, synchronizing and blanking signals are fed from an external source, the generator is capable of producing four types of signals (Figs. 3, 4, 5 and 6).

The step signal, as seen on the face of a kinescope (Fig. 3), resembles a photographic step tablet such as that

* J. H. Roe, "Standardizing and measuring video levels in a TV station," *RCA Broadcast News*, 65: 30, July-Aug. 1951.

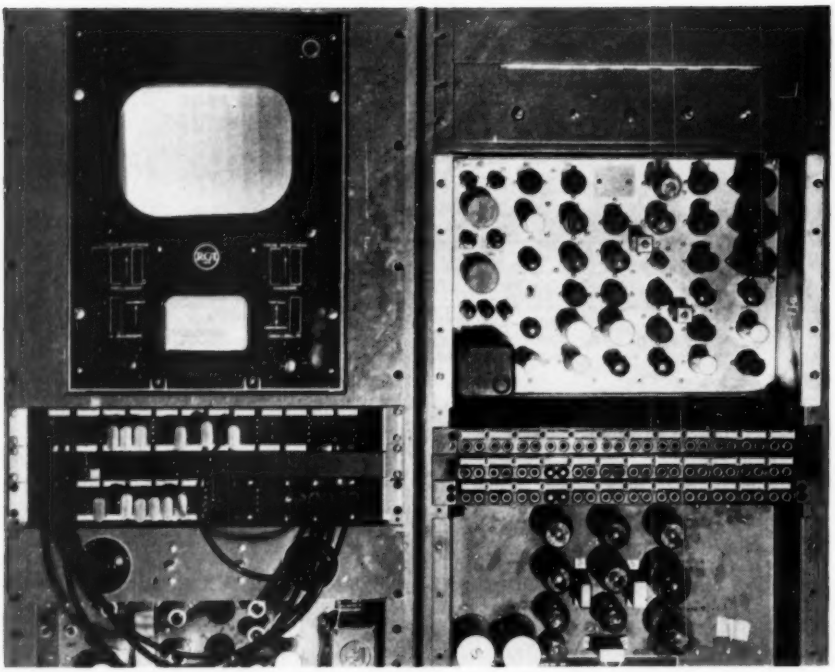

Fig. 2. Step generator in rack adjacent to TM-5A master monitor.

used in intensity-scale sensitometers. The number of steps can be adjusted, by means of a potentiometer, from 3 to 22. However, it is usually set to produce 10 steps, simply because the resulting 10 density strips on each frame of motion picture film are large enough to be read easily by a densitometer. Step 1, reading from the bottom, is adjusted to simulate black level, i.e., 10 units above blanking level. Each succeeding step raises the signal 10 units above its predecessor until step 10 represents 100 units or peak white.

A second type of signal (Fig. 4) produced by the step generator is a rectangular pulse, approximately 10 μsec in width, and occurring at the horizontal scanning rate of 15,750 cycles/sec with an amplitude controllable from blanking level to peak white. A pedestal control can be adjusted simultaneously to simulate black level while the pulse is adjusted to 100 units. In this way the extremes of picture information relating to a given video signal may be represented. If desired, the pulse may be eliminated and the pedestal control adjusted to any level between zero and 100 units, thereby producing a blank raster of uniform brightness dependent upon the pedestal setting.

An external input position permits the introduction of various types of test signals, such as the 4,500-cycle sine wave shown in Fig. 5, or the 15,750-cycle sine wave seen in Fig. 6.

An oscilloscope with a 7-in. calibrated screen plays an important part in exposure control, for not only can it be used in conjunction with the step generator signals to determine proper exposure settings for the 5WP11 kine-

scope, but it can also monitor the television picture signals being recorded and immediately indicate to the operator discrepancies in level which might need correction. The 7-in. screen is preferred because it presents an expanded scale upon which level variations can be readily detected.

An ingenious little device used to advantage by our staff is a spot photometer made in England by Salford Electrical Instruments, Ltd. Although not currently in operational use in NBC Hollywood it has served well to establish the control procedure under discussion and might well serve other interested persons. Brightness values in log foot-Lamberts can be read directly from small areas on the face of the recording kinescope. Since visual matching of the luminances of fields of different colors presents difficulty, it is desirable to measure the photo-actinic output of the phosphor; a blue filter may also be installed in the photometer as an aid in matching the kinescope phosphor color. A calibrated density wedge, incorporated in the instrument, is visually compared through an eyepiece with the brightness produced by the small area being measured. Operation, in this respect, is much like that of a Capstaff-Purdy Densitometer. Since this photometer can read minute areas on the face of the kinescope it can be used to determine the brightness of the various steps of the step generator signal, particularly the two extremes, step 1 and step 10. Kinescope brightness may therefore be set in accordance with predetermined brightness values to produce desired exposure on the film negative.

While this is a very useful instrument, it has three operational disadvantages:

1. The human element enters into the readings, hence no two people will get precisely the same results.

2. Due to slight differences in kinescope phosphor color, it is often difficult to decide when the two comparative densities are perfectly matched.

3. Calibration drift occurs rapidly due to insufficient current capacity in the exposure lamp supply. One remedy for this is an auxiliary battery box supply.

Use of the spot photometer soon led to the design and construction of a different device eliminating the human element from the kinescope brightness measurements. This was the phototube amplifier shown attached to the hood in Fig. 7 which, although not impressive in appearance or complexity, has introduced a high degree of accuracy into our exposure control measurements. Positioned just outside the recording light path, the type 929 high-vacuum phototube receives light from the kinescope face during scanning and no light during the horizontal and vertical retrace times.

If employed only with a blank raster produced by the step generator this phototube and its amplifier produce an electrical waveform having an amplitude proportional to the intensity of the light output from the kinescope. By frequent calibration of the phototube amplifier an exact comparative measurement of light output can be obtained and fed to the calibrated 7-in. oscilloscope (Fig. 8). A low-gain switch position is used for peak-white measurements where much light is produced by the kinescope, and a high-gain switch position is provided for black-level measurements where a very low level of light output is produced by the kinescope. Thus the two extremes of exposure, namely peak white and black level, can be accurately set with no "human element" error such as occurred with the spot photometer.

In addition to the electronic instruments thus far mentioned, two conventional instruments well known to the film industry are employed. These are the Eastman Processing Control Sensitometer, an intensity-scale type, and the Eastman Densitometer, known generally as the Capstaff-Purdy Densitometer after its inventors.

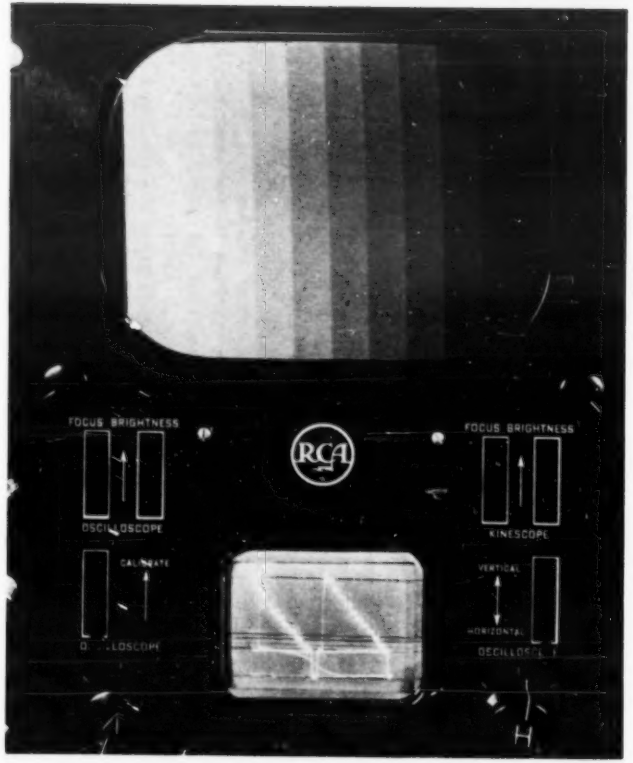

Fig. 3. Step-generator step signal as seen on master monitor kinescope and oscilloscope.

Fig. 4. Step generator rectangular pulse.

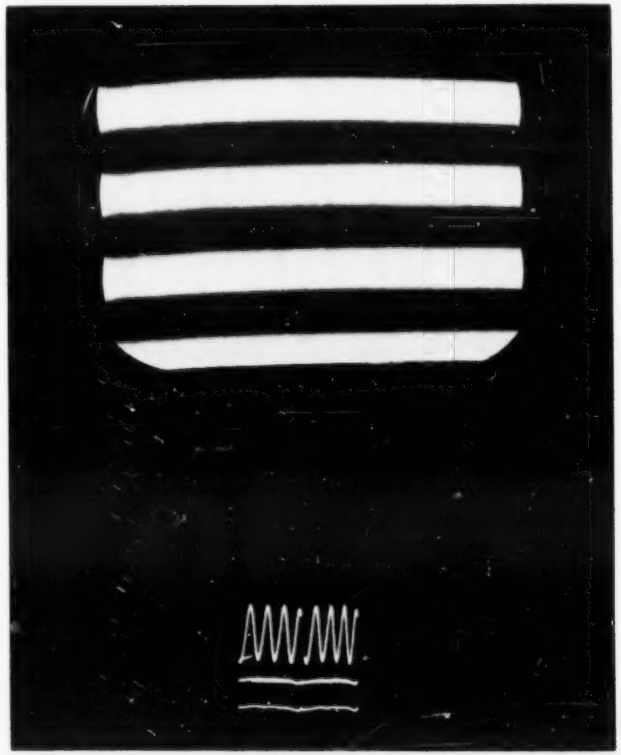

Fig. 5. 4,500-cycle sine wave signal produced by step generator.

Fig. 6. 15,750-cycle sine wave signal produced by step generator.

Operating Procedure

The operating procedure used to maintain accurate exposure control with the instruments described above may be classified in four categories:

1. Calibration of equipment.
2. Peak-white measurements.
3. Black-level measurements.
4. Sensitometry.

Calibration of Equipment. As indicated earlier, it is extremely important that all units in the recording plant be carefully calibrated, since amplitude drift or level discrepancies affect film exposure. The five operational steps for calibration are as follows:

(1) Adjust the 60-cycle calibrating voltage to exactly 1.4 v peak-to-peak as read on the meter previously described.

(2) With the oscilloscope selector switch in the "calibrate" position, adjust the vertical amplitude of the TM5A master monitor oscilloscope until the 1.4-v calibrating signal exactly fits arbitrarily prescribed lines for the 1.4-v video signal.

(3) Apply the 1.4-v calibrating signal directly to the input of the 7-in. oscilloscopes at each recording position and adjust amplitude to prescribed lines on the tube face.

(4) Apply the 1.4-v calibrating signal to the input of the phototube amplifier and adjust its gain until the output as seen on the scope fills prescribed calibrating lines.

(5) All electronic measurement instruments in the system have now been calibrated.

Peak-White Measurements. There are several means by which peak-white measurements can be made satisfactorily. From an operational standpoint the most desirable is as follows:

(1) The familiar step signal produced by the step generator is used and the three important steps, 1, 2 and 10, carefully adjusted to prescribed lines on the face of the master monitor oscilloscope.

(2) This signal is then fed to each recording position through exactly the same distribution amplifiers and coaxial lines as will be used for the picture signal to be recorded later. The 7-in. oscilloscope is then connected across the output of the recording video amplifier, and the amplifier gain adjusted to the desired amplitude as shown on the calibrated oscilloscope.

(3) There is, of course, a fixed relationship between signal amplitude and kinescope light output, hence also maximum film exposure.

Black-Level Measurement. A somewhat different procedure is employed for black-level measurement since it has been found to be much more critical than peak-white measurement.

(1) The blank raster, or pedestal, position of the step generator is used, carefully adjusted to 20 units on the master monitor oscilloscope. The 20-unit adjustment, instead of the customary 10 for black level, was chosen because it produced a density of about 0.1 on the film, a value far enough removed from the base fog region to give more consistent operating data.

(2) The 7-in. oscilloscope at each recording position is now connected to the output of the phototube amplifier. The black-level control is then adjusted to produce the desired amplitude as indicated on the calibrated oscilloscope. This, of course, will determine the minimum exposure, or black level, on the film.

The two extremes of the anticipated video signal, peak white and black level, have now been set.

Sensitometry. The final test of the above is to make an exposure, develop the film, and measure the resulting densities.

(1) This is done using the step signal carefully adjusted as described.

(2) The test exposure is made about two hours before recording time to permit development, analysis and readjustment.

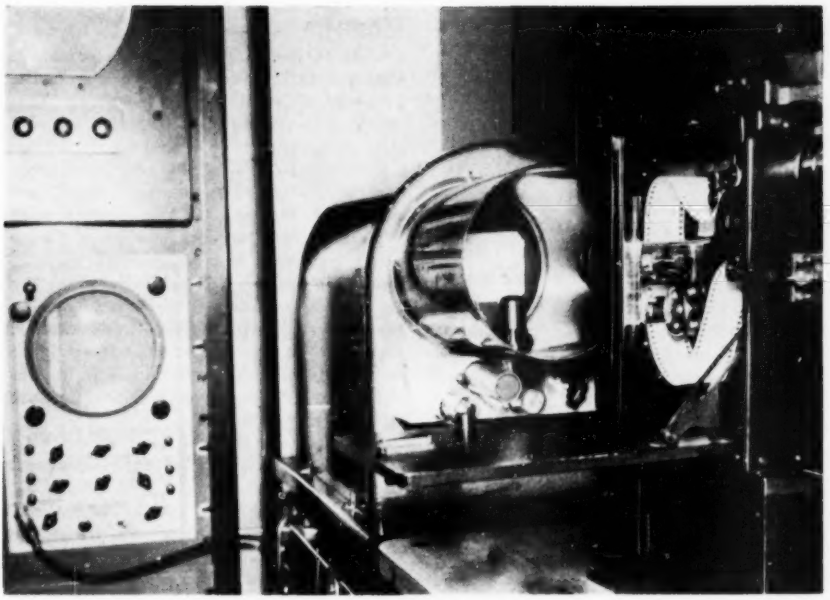

Fig. 7. Phototube amplifier mounted in operating position on kinephoto monitor.

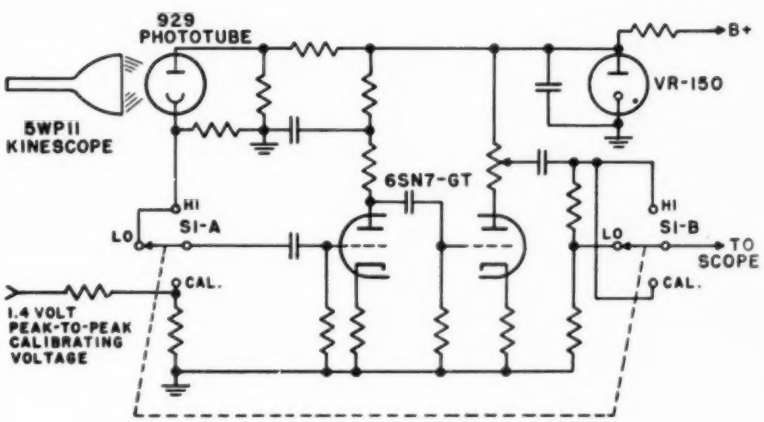

Fig. 8. Schematic diagram of phototube amplifier.

(3) An intensity-scale sensitometric exposure is made on each film recorded, whether test or show, to determine processing conditions at time of development.

(4) Step generator densities, particularly those resulting from steps 1, 2 and 10, are read and brought to the attention of the operator at each camera position. If slight adjustments in exposure are indicated the operator makes them just prior to recording time.

(5) A short section of step signal is recorded either at the head or at the tail of each show. An intensity-scale sensitometric exposure is also made.

(6) A characteristic curve is plotted for each show as well as a step density plot resulting from the step generator exposure.

(7) The data thus accumulated are recorded in an operating log maintained at each camera position as well as in our sensitometric file.

The above procedure, described in its necessary detail, may sound laborious and time consuming. Actually the whole process can be accomplished in a few minutes, with spot checks requiring less than 30 sec. Consistency of exposure, over long periods, resulting from this method is ample testimony to its value, and we are convinced that the quality of our product is greatly enhanced by its use.

Discussion

John G. Stott (Du-Art Film Laboratories): Can you tell us how you take care of the problem of resolution of scanning lines when you do the densitometry of that step-wedge tablet?

Mr. Lovell: When we read the step-wedge with the densitometer? Well, actually we ignore it. We realize that probably there are some strange things going on there, but we haven't tried to analyze what the effects really are. We do get a perfectly satisfactory density reading and while from a theoretical standpoint it may not be what it would be on a normal film, nevertheless it is consistent and it does give us operating data which are very useful.

Mr. Stott: Well, you have to do your densitometry with a visual instrument then, is that correct?

Mr. Lovell: We use the Eastman Capstaff-Purdy Densitometer to make all our readings.

Mr. Stott: You would probably run into some difficulties then if you used the electronic or photocell type of densitometer?

Mr. Lovell: I believe not. We have used a regular ERPI Densitometer with no detrimental effects. We get comparable readings and, of course, they don't read exactly the same, but no two densitometers ever do, I believe, and as long as there is a constant difference between the two, we are happy. I should say that perhaps two ERPI Densitometers do read the same, but not necessarily two different types of densitometers would read the same.

Time-Zone Delay of Television Programs by Kinescope Recording

By RALPH E. LOVELL

A technique is described whereby network television programs can be delayed for three hours to compensate for the time differential between the east and west coasts. The use of 35mm film for picture and magnetic recording for sound insures high-quality reproduction.

In television, as in radio, the matter of a three-hour time difference between the east and west coasts of the United States creates a serious problem in releasing programs at a time which will reach the desired audience at all points throughout the country. In radio, the problem has for years been solved by disc or tape recording with appropriate hours of delay in playback to compensate for the time-zone differential. The opening of the coast-to-coast television network in 1951 created a similar challenge to kinescope recording of television programs.

As in radio, there are two aspects of this delayed broadcasting. Many live television programs intended primarily for eastern evening reception originate in Hollywood in the late afternoon, but are not released to the west coast cities at the time of origination because the desired western audience is not available at that time. These programs can now be recorded in Hollywood and reproduced — usually three hours later — for viewers in Los Angeles, San Francisco, Seattle and San Diego, at the west coast evening hour desired by the sponsor or network. Conversely, many shows originate in New York, or other eastern cities, at a time convenient to eastern audiences, but again they are three hours too early for western audiences. These programs can likewise be recorded in Hollywood at the time of their live origination in the east and be telecast throughout the west coast three hours later. The terms "Quick Kine" or "Hot Kine" have been coined to describe such three-hour delay recordings, the techniques for accomplishing which are new and rather complex, and depend upon close coordination between recording, processing, editing, projection and messenger personnel.

Figure 1 shows a portion of the kinescope recording room at NBC Hollywood. On the right is a 16mm single-system camera, and on the left a 16mm sound recorder of conventional design.

Presented on October 7, 1952, at the Society's Convention at Washington, D.C., by Ralph E. Lovell, National Broadcasting Co., Sunset and Vine, Hollywood 28, Calif.

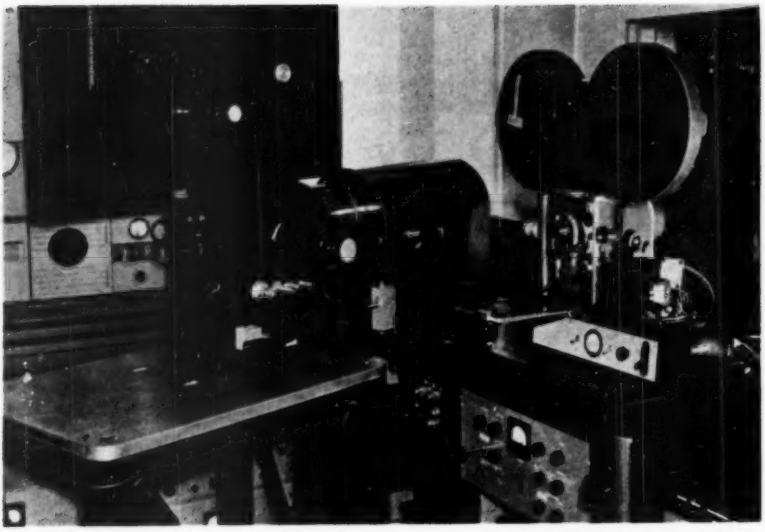

Fig. 1. A portion of the kinescope recording room at NBC Hollywood. On the right is a 16mm single-system camera, on the left a 16mm sound recorder, and in the center a 35mm camera.

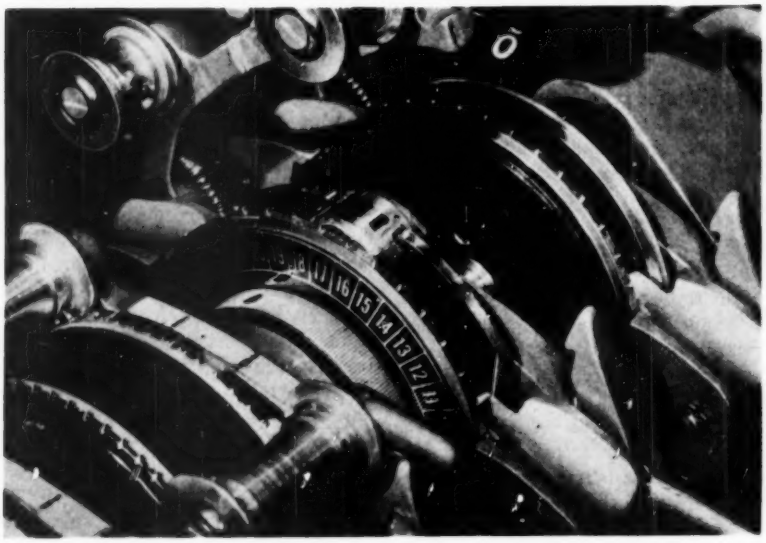

Fig. 2. A 35/16 synchronizer with a magnetic reproduction head for editing purposes.

In the center is one of the three 35mm cameras installed about a year ago to accomplish the three-hour delay recording to be described here. It is to be noted that the 35mm camera is equipped with a 3000-ft magazine, permitting a running time of 33 min. The 35mm cameras used thus far have been of the "silent" type; that is, they record only the picture portion of the program. It is expected that single-system 35mm cameras capable of recording both picture and sound will soon replace the silent cameras shown here. The sound portion of the program is currently being recorded very successfully on 16mm perforated magnetic film, running at the 16mm speed of 36 fpm. For this purpose, two rack-mounted, synchronously driven RCA magnetic recorder-reproducers are employed. Two RCA 16mm optical recorders which have been modified by the addition of a recording head and a monitor head may also be used to perform magnetic recording. Lip synchronization between picture and track is cued by insertion of an audio tone in both picture monitor and sound recorder, thereby creating easily recognizable patterns comparable to studio slating marks.

It has been the experience of broadcasters for many years that a small investment in an extra copy of a disc or tape is amply repaid because some accident may damage the "A" copy recording. This same philosophy applies to kinescope recording: hence most companies make two negatives, one being considered the "A" copy, the other the protection, or "B" copy. It is in this quick kine "B" copy operation that NBC's single-system, 16mm cameras are particularly useful, for they permit the recording of both a picture negative and a photographic, variable-area, direct-positive, sound track on one, single-perforated strip of film. At the end of each half-hour of quick kine recording, both the 35mm and 16mm magazines are immediately removed from the cameras and taken into the darkroom for unloading. It is to be noted that only two and a half hours now remain till the film must be processed, edited, and in the projector, ready to be rebroadcast to the west coast audience extending from San Diego to Seattle.

The 16mm single-system "B" copy is developed by NBC personnel in one of two Houston Model 22 processing machines. A half-hour program requires about 45 min for complete processing, including a waxing treatment to enhance projection. Meanwhile, the 35mm "A" copy negative has been placed in its original light-tight carton, and handed to a waiting messenger who drives a few blocks across town to a commercial film laboratory where a crew is prepared to process the film immediately. Since the film used for the kine camera negative is actually a low-contrast positive, it runs through positive developer at the normal machine speed of 125 fpm, resulting in a negative gamma of about 1.60. It therefore creates no special problems, such as changes in machine speed or threading, and can be connected directly to other positive work going through the machine. After the film passes through developer, hypo and wash, it receives a waxing treatment which lubricates the film to permit immediate projection. Approximately one hour after the 2700-ft roll of undeveloped film reaches the laboratory, it comes off the dry end where the messenger is waiting to return it to the television station for editing.

During the time the two negatives are being developed, the editing personnel are not idle. With the aid of a magnetic sound reader, the synchronization tone-bursts at the head and tail of the 16mm magnetic film are located and marked with a wax pencil. Identification leaders are prepared in advance and attached to the All-Purpose Film Leader which has replaced the Academy leader for television films. The 16mm single-system "B" copy negative then arrives from processing, and is made ready for projection by the addition of the prepared

Fig. 3. Quick kine projection facilities; a 35mm projector with an interlock motor which drives the 16mm magnetic film reproducer in the background.

leaders. The return of the 35mm "A" copy negative is the signal for prompt action by the editing personnel who place the film on a 3000-ft, double-sided flange and proceed to line it up in the synchronizer with the 16mm magnetic sound track. At the request of NBC, the Moviola Company installed a magnetic reproducing head in one of the 16mm wheels of a 35/16 synchronizer (Fig. 2), thereby making it a combination sound reader and synchronizer, and permitting rapid and safe handling of the two films. Identification leaders are attached, a special adhesive marker is applied to the magnetic track for accurate thread-up positioning, lip synchronism is checked at both ends of the show, and

the 35mm negative is mounted on a 3000-ft projection reel. All of the above processing and editing, including transportation of the 35mm negative across town twice, has taken approximately two hours, leaving about a half-hour for threading in the film projection studio.

Close examination of Fig. 3 reveals a selsyn interlock distributor motor, chain-driven by the RCA 35mm television projector motor. This interlock motor supplies driving power to one of the RCA rack-mounted 16mm magnetic reproducers located at the right of this picture. The 16mm magnetic track therefore runs in perfect lip synchronism with the 35mm picture negative. By simply flipping the iconoscope polarity switch to "Negative" and reshading accordingly, a positive picture image of high quality is obtained from the negative film. The single-system "B" copy is run in a 16mm projector on an adjacent iconoscope, so that in the event of trouble with the "A" copy, a flick of a button will put the "B" copy picture and sound on the air.

If 16mm release prints are required for syndication, they are obtained by reduction printing from the "A" copy 35mm picture negative and by contact printing from a 16mm negative sound track. Picture quality thus obtained on 16mm release prints is superior to that obtained by contact printing from a 16mm negative of the same subject matter.

Although this three-hour time zone delay operation may sound very precarious and nerve wracking, it has been in daily use for one year with very few errors and with picture and sound quality rivaling that of many live shows.

History and Present Position of High-Speed Photography in Great Britain

By W. DERYCK CHESTERMAN

The history of high-speed photography in Great Britain is outlined, beginning with intermediate-rate cameras, defined as those in which the film is transported continuously through the camera mechanism at speeds not exceeding 40 m/sec. Then follows a survey of drum cameras, in which a single loop of film is transported at speeds up to 240 m/sec on a rotating drum, or where images are swept along the stationary film at this rate by moving optical parts. Recent developments in light sources of short duration are discussed and the review concludes with a description of some research studies in zoological, biological and medical sciences, and some recent military applications.

THE TERM HIGH-SPEED PHOTOGRAPHY is now generally used to cover a wide range of observational techniques in which photographic images are recorded to examine the sequence of happenings in a rapid event. Sometimes a series of pictures is produced for subsequent cinematographic projection, or alternatively, separate individual pictures permit study of a repetitive motion of a repeatable event, by subsequent analysis. It is convenient to classify the methods both by the repetition rate of taking pictures and by the individual picture exposure time. Each of these fundamental variables is of vital importance to the camera designer and to the research worker who uses the observational tool which has been devised. The progress of high-speed photography in Great Britain, as in Europe and the United States, may be considered as a search for methods of higher repetition rate together with ever shorter exposure times. It is always most desirable, but also difficult, to maintain the highest picture quality while improving these other variables.

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by W. D. Chesterman, Royal Naval Scientific Service, Admiralty, London, England.

Intermediate-Rate Cameras

In the present paper we shall deal first with intermediate-rate cameras, or those in which the film is transported continuously through the camera mechanism at speeds of less than 40 m/sec. These cameras are of two categories — those in which the film is moved intermittently and is stationary at the time of exposure, and those in which the film moves continuously at a high rate, the images being optically stabilized on the

film by a variety of means. The author has reviewed elsewhere[1] the variety of instruments made in Great Britain, Germany, France and the U.S.A. during the last 30 years. Unlike some cameras in the higher ranges of speed, many of these instruments were produced commercially in numbers of a few dozen, and in rare cases, of a few hundred. In Great Britain the emphasis has been on types using 35mm rather than 16mm film. This may well be due to the feeling among many workers that the large picture size is a great aid to certain detail analysis, and for this reason the higher repetition rate possible with smaller format films (16mm and 8mm) has been sacrificed.

One may instance three instruments. For speeds up to 240 or 300 frames/sec, the Vinten HS. 300 is a valuable and flexible camera.[2] It is in the category of a normal slow-motion cine camera, and has the facilities normally associated with fine-quality studio cameras. It has been widely used in field work and has proved capable of producing a picture quality equal to that of the best cine cameras. The maximum repetition rate at which it can be used is 10 times normal cine-frame rates. Beyond this, cameras using a different film-transport system are used, the film motion being continuous rather than intermittent. Optical stabilization may be achieved by a lens disk of 48 matched objectives, and Geary[3] has described the Vinten HS. 2000 camera which was produced during the last war for ballistics research.

A more recent development in 35mm cameras was constructed by Myers and the author[4] in 1950, at the firm of Acmade Ltd.

In this instrument, normal picture formation is stabilized on the film by a spinning cubical prism of the conventional form. In order to achieve a powerful film drive coupled with high acceleration to full speed, the design is based on a large-diameter 24-frame sprocket, and the film is in contact over half the circumference. The sprocket is driven from the prism shaft with appropriate reduction gearing. The camera takes 2000 normal-size 35mm frames/sec, ready for cinematographic projection. With an octagonal-section prism the maximum rate becomes 4000 frames of half height per second. With the prism removed the camera can be used as an oscillograph recorder with a film-transport speed of 40 m/sec. The optical systems embodied in the camera permit the simultaneous triggering of a power stroboscope, synchronized with the picture formation. In a direction at right angles to the main picture-forming axis, a collimated light beam passes through the spinning prism on to a photocell to trigger the light source of a short-duration flashtube. It is also possible to mask off a part of the picture area and then image the spot deflection of a high-brightness oscilloscope onto a part of the rapidly moving film. The normal timing markers at 1000 cycles are recorded on the film rebate.

This camera has been widely used during 1951 and 1952, in Great Britain, for cavitation studies, and for various ballistic research. It is a convenient instrument for photomicrographic studies at high speed. The stimulus and achievement of similar American developments is readily acknowledged.

In Great Britain there has not yet been constructed, to the writer's knowledge, a 16mm camera in the intermediate speed range. This is probably due to the availability of American, German and French instruments, which have often been in small quantity production.

Drum Cameras

At rather higher picture repetition rates, it is no longer possible to transport film at the necessary speeds continuously through a camera mechanism. Drum cameras have been devised to take pictures at rates from 2000 to 200,000 pictures/sec, depending on the picture

size and the elaboration of the instrument. The earliest British type was termed the Heape and Grylls Machine, and was described by Connell[5] in 1926. At that time, a quarter of a century ago, it was a considerable optical achievement. By rotating a 1.73-m drum at 1000 rpm a transport rate for the film of nearly 100 m/sec was obtained. Optical image formation and stabilization were carried out by a disk of lenses rotating in front of the film plane. The camera could take stereoscopic pairs of pictures and a picture repetition rate of 5000/sec was obtained.

In those days of very slow emulsions, lighting the subject presented a prodigious problem, and two searchlights were used to focus the light energy (and heat!) on the subject. Flash discharge sources or pulsed arcs make the present-day problem far easier to solve. The Jenkins camera[6] was of the same period and used the same principle of optical compensation.

Altogether simpler instruments were made for specialized tasks by Baxter[7] and Brailsford.[8] The latter used a rotating cubical prism block and a simple loop of film on a small drum. Fifty successive pictures of the event were recorded, and the cameras were eminently suitable for self-luminous subjects such as the changes in a welding arc.

The Second World War was the stimulus to more elaborate constructions. Notable amongst these was the Scophony Camera,[9] which, unlike the earlier four cameras mentioned, was produced commercially in small numbers. This instrument was one of the first to succeed in combining the high repetition rate of 10,000 pictures/sec with a large image size of 24 × 24 mm. A mirror drum with 49 facets rotated concentrically with the film drum to achieve image stability during exposure. A film drum of 0.39-m diameter rotated at 12,000 rpm to give a film-transport speed of 240 m/sec.

A camera of quite different design, the Marley camera, has already been reviewed in this *Journal* by Shaftan[10] and also by Jones and Eyles.[11] The high repetition rate of 100,000 pictures/sec is obtained at the rather low aperture of $f/64$, but the camera is most suitable for self-luminous studies in explosion research. Each image shows the event from a slightly different aspect, and this feature must be taken into account when reconstructing the spatial development of the rapid event.

Henry[12] has made and used a simple and cheap form of drum camera combined with repetitive air-spark illumination to take excellent pictures of loom behavior in cotton processing research. The Cotton Research Association is one of the groups in England well aware of the importance and potentialities of high-speed photography.

In a review of this kind, which attempts to cover both the past history and the present position in this field, it is not, perhaps, amiss to describe a project still in progress. The author has been working in collaboration with Barr and Stroud Ltd., for the last four years, on an ultra-high-speed drum camera in which the images are formed rapidly on stationary film by somewhat novel means. The camera is designed to operate up to 25,000 frames/sec at a picture size of 24 mm square. The aperture of the system is $f/8$ and all images are seen from the same aspect. Any standard 35 mm film stock can be used in the instrument.

In drum cameras in which the images are formed on the film by a rapidly spinning central mirror, the optical systems are of two types. In both types a primary objective forms an image of the event on the axis of the spinning mirror. Surrounding this mirror is a ring of secondary lenses which form a set of images on the stationary film. In systems which require image-rotation compensation devices, the axis of rotation of the spinning mirror is coincident with

the optical axis of the primary objective, and the plane of the mirror surface is generally at 45° to the primary objective axis. Systems which do not require image-rotation compensation have the axis of rotation of the mirror normal to the optical axis of the primary objective. The Barr and Stroud camera is a system of the latter type, and there is only one moving part. The central prism design is the most important single feature of the camera. It consists essentially of a sphere of glass divided along a diametral plane; the flat surfaces are silvered to form plane mirrors and the sphere is then joined together again and held in a steel cage. The prism unit, which is 6 in. in diameter, spins at 7,500 rpm to sweep the images across 100 secondary lenses. The film drum is 58 in. in diameter, and the whole camera weighs about 1 ton. From preliminary photographic tests already made the image quality appears to be extremely good. A full description of the camera will be published on completion of the project. An interesting feature of the design is that the instrument can work at unit magnification.

Light Sources of Short Duration

Air Sparks. The electric spark in air was the earliest light source used for the study of rapid events by photography. Fox Talbot[13] suggested its use a century ago, and the air spark is still used in ballistic research laboratories all over the world. The time duration is less than 1 μsec and by the use of delay line discharges can be made as low as 0.1 μsec. Sixty years ago Lord Rayleigh[14] described the use of the spark for the study of air jets and thin films, and at the same time Worthington[15] was carrying out his beautiful work on the study of splashes and the impact of liquid drops on solid surfaces. Wood[16] studied the properties of sound waves in air by these methods. Boys,[17] one of our greatest experimenters, took the first pictures of bullets in flight, and in addition, proved by optical means how short was the duration of his sparks. Today, Adams[18] and his team at the Armament Research Department use sparks widely for their work and have combined this form of light source with multiple-gap systems for studying the plastic bending of a steel rod under very high impact shock.

Guided sparks, in which the discharge is made to take place along prearranged channels, permit a more efficient use of the light source in combination with the optical systems necessary for these studies. The relatively poor conversion of electrical energy to light can be partly overcome by using emulsions having high blue sensitivity.

Repetitive flashing of a single gap is also used, the successive images being received on a conventional drum camera, or on a stationary plate if the translational velocity of the event causes the images to move across the image plane.

Sparks in Rare Gases. Condenser discharges in argon, krypton, xenon and other gases have been studied in very great detail by H. E. Edgerton.[19] His pioneer work, dating from 1931, has been reported in this *Journal* and many others. This research has provided a strong stimulus to other laboratories, particularly where repetitive flashing light sources, with a high degree of reliability and repeatability of behavior, are needed. Energy ranges in the lamps have been from one to many thousands of joules in the single-flash types, and the flash times have ranged from about a microsecond to as high as a millisecond. In Great Britain Aldington[20] has made notable contributions to the field and developed a wide variety of lamps, generally xenon-filled, for many research and industrial purposes.

For ballistic research Mitchell[21] developed an argon-filled lamp called the Arditron. Filled to high pressure and operated from a low-value capacitor, the duration can be of the order of a few

microseconds. This tube has been produced commercially by several firms and is widely used in many laboratories.

The author and his colleagues have studied in some detail the use of xenon for very short-duration flashes.[22] The work was at first concentrated on making a repetitive light source for flashing rates up to 4000/sec. Photographic duration for a 4-j flash was reduced to 5 μsec. Stamp and Coghlan[23] have described the method of measurement of this duration. The work reached a successful conclusion in the development of a high-power stroboscope[22] which can be used in conjunction with the Acmade camera.[4]

The research on xenon is still in progress. The effect on the electrical discharge characteristics of changes in gas pressure, energy in the lamp, and tube arc length have been studied. The design of the lamp must be integrally related to the external circuit conditions in the discharge loop. In the author's opinion there is still much necessary fundamental research to be done on the short-duration spark discharge in xenon. It is the interrelation of electrical transient and photographic afterglow which it is most important to understand. The enhanced light output of the xenon discharge over that of the air spark makes the former a most valuable source for flash work.

Schlieren Systems

Schlieren systems have been widely used by the Safety in Mines Research Laboratory in Great Britain in their studies of "fire-damp" explosions. Aerodynamic research institutions use schlieren optics in various forms for airflow research. Among recent interesting contributions one may mention the use by Holden and North[24] of a color emulsion for their schlieren images. Quantitative analysis is made easier by this development.

The author has used the collimated double-mirror schlieren system for the study of ultrasonic patterns in a water tank. The great advantage is that the pressure fields are not disturbed by the insertion of any measuring instruments or gauges.

Electrooptical Shutters

There is undoubtedly a wide field of application ahead for electrooptical shutters, when very short exposure times are required. As is well known, the simplest system employs the Kerr effect, in which rotation of the plane of polarization of a light beam occurs when a high voltage is applied across a glass cell containing nitrobenzene. Exposure times of 0.1 μsec have been achieved by these systems and Froome[25] has applied repetitive pulses at a high rate to get a succession of pictures. He was studying[26] the behavior of the cathode spot on an undisturbed liquid surface, and since the translational movement of the self-luminous event was high, successive phases could be studied on a stationary plate. The photographic aspects of Kerr cell shutters have been critically discussed in some detail by Holtham and Prime,[27] members of the Liverpool University research team under Meek, who have made various original contributions in high-speed photography over a number of years in Great Britain.

The image-converter tube is now beginning to be widely explored as an electrooptical shutter of negligible time inertia and considerable flexibility of application. Courtney-Pratt[28] showed the potentialities of the system. In addition, Prime and Turnock[29] have investigated the use of an iconoscope tube and shown that it has promising possibilities.

Some Research Studies

Space forbids more than a brief mention of the diverse subjects studied with these high-speed methods. In Great Britain, as in many countries, some of the observational tools of war have

found interesting applications in peacetime research. This is particularly true in the zoological, biological and medical fields.

Zoological, Biological and Medical Applications. Here one may quote motion studies of insects, birds and fish in their natural environments. Chadwick[30] investigated wing-beat rates in his genetic studies of Drosophila, and other workers have shown experimentally a wide wing-beat rate from 6 to 300/sec by these means. Hosking[31] has made many beautiful studies of birds in flight, using flash-discharge illumination. Brown[32] has studied the wing movement of various birds in the laboratory, regarding the movements from the standpoint of a mechanical system. The importance of different wing muscle groups has been clarified. The top speed of the wing of a carrier pigeon has been proven by this means to be as high as 60 mph.

The author and his colleagues have studied fish movements in slow motion with underwater cine cameras operated by a frogman with air-breathing self-contained equipment. A most interesting unsolved hydrodynamic problem is the motion of a porpoise at full speed, which occurs without cavitation.

In medical research the flash source is a most valuable "cool" light. Potter and McDonald[33] have studied the speed of arterial blood flow. There is undoubtedly much work to be done in high-speed photomicrography using flash sources.

Military Applications. The greatest field of all applications is of course in military science, in particular for ballistic research underwater and in air, and for explosion research underwater and in air. As in U.S.A., much work has been done in Great Britain with intermediate-rate cameras and flash sources.

Cavitation research, whether concerned with propellers, impeller systems or hydroelectric schemes, has made wide use of high-speed photography. The problems of underwater illumination have been studied by the author[34] in relation to many of these problems.

Recent work which is typical of the investigations has been described by Senior,[35] and more recently by Taylor,[36] the latter in respect of one of the atomic bomb explosions.

The Future

In Great Britain there have been many notable contributions to the advance of the methods and applications of high-speed photography. There is, however, still a lack of consciousness, except in some major research teams, of how great are the potentialities ahead. The engineer, the physicist and the worker for whom the technique is required must form their plans with the greatest coherence. Progress in the future will then arise from their common outlook.

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Rapid-Sequence Camera Using 70mm Film

By CHARLES A. HULCHER

This paper presents the problem of obtaining relatively large photographs in sequence at frame rates up to 50/sec. Design characteristics required for a camera suitable for obtaining photographic data of missile launchings and flights with negatives $2\frac{1}{4}$ in. wide and $2\frac{1}{2}$ or 5 in. long are enumerated. The intermittent film transporting mechanism and shutter system used in the solution of this problem are described.

THE ADVANTAGES of a large negative for detail study of photographic data are thoroughly recognized and are employed wherever the existing conditions permit. However, in cases where photographic data are required in sequences of more than several frames per second, the desirable characteristics of the large negative have, of necessity, been compromised in favor of the 35mm or 16mm motion picture frame sizes. The Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics at Langley Air Force Base, Virginia, has developed a rather unique camera capable of producing relatively large negatives at sequence rates considerably higher than heretofore available. The basic principles of this camera have since been incorporated in a refined model which has recently been placed on the market. While this camera was developed primarily to obtain photographic data from rocket-powered missiles, it has proven especially useful in numerous other fields. These instruments are now in service in several stations in this country and in Canada.

Presented on October 10, 1952, at the Society's Convention at Washington, D.C., by Charles A. Hulcher, Charles A. Hulcher Co., Inc., 40 Manteo Ave., Hampton, Va.

The Problem

Preliminary specifications were established as follows:

(1) Provide a negative size at least 2 in. wide and 5 in. long. This was considered a minimum frame size for fixed cameras photographing missile launchings. The 5-in. dimension could be aligned with the proposed missile trajectory. This would provide for the use of focal lengths long enough to obtain the required image sizes and still maintain enough field to insure photographic coverage.

(2) Provide minimum sequence speeds of at least 10 frames/sec.

(3) Provide a shutter system which would efficiently stop the motion without excessive distortion.

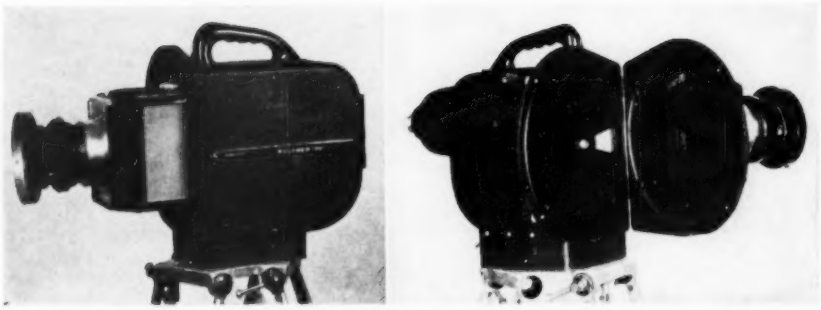

Fig. 1. Exterior view of the Hulcher 70mm rapid-sequence camera.

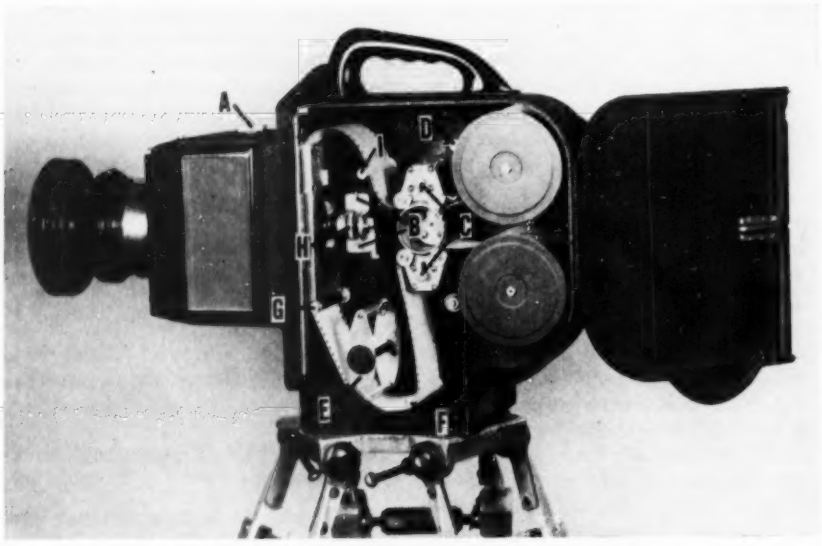

Fig. 2. Interior view of the film transporting system; see text for description of keyed parts.

(4) Provide for a high degree of reliability. This was considered very important since jamming or other malfunctioning of the camera could result in total loss of records in the event of some mishap at launching. While these specifications covered the major requirements, it was also considered desirable to develop a camera rugged enough to withstand the abuse associated with the installation of these instruments on a sandy ocean beach, be reasonably simple to operate and maintain, utilize the available lens systems of the K24 Aero Camera and not be excessive in weight or cost.

The Solution

A prototype camera was subsequently designed and built and has since proven successful in meeting the requirements set forth in the specifications. This

camera utilized 70mm perforated film on 100-ft daylight-loading spools. It produces negative sizes of either $2\frac{1}{4}$ in. by 5 in. or $2\frac{1}{4}$ in. by $2\frac{1}{2}$ in. It operates at variable sequence speeds up to twenty-five 5-in. pictures per second or up to fifty $2\frac{1}{2}$-in. pictures per second. Its double rotating shutters, operating close to the focal plane, provide high motion arresting characteristics. The camera contains no reciprocating parts and since all moving parts are balanced and rotate at a constant preset speed, the camera has proven remarkably reliable and trouble-free. Rugged cast aluminum alloy construction and the absence of any small or intricate parts have proven more than equal to the abuses inherently associated with this type of installation.

Description

The exterior view shown in Fig. 1 indicates the general form of the camera. The lens mount slides in machined grooves in the front casting and may be removed to insert the desired lens. Focusing is accomplished by rotating the knob on the top of this housing which swings a front surface mirror into a 45° position reflecting the image onto the ground-glass screen for focusing. The 6-in. square base is designed to fit standard tripods. The camera weighs approximately 30 lb. Figure 2 is an interior view of the camera's film transporting system. Film supply from spool D is fed over the sprocket and held in position by the film hold-down device C. It then passes in an easy loop over roller I through the pressure plate behind roller G, under the interrupter E and thence under the sprocket and on to the take-up spool. Both the sprocket and the interrupter rotate in a counterclockwise direction and at the same speed. Each revolution of the sprocket feeds $5\frac{1}{10}$ in. of film in on the topside and out on the bottom to the take-up spool. Except for the action of the interrupter, the film runs at a constant speed from the supply spool through the camera and on to the take-up spool. Rotation of the interrupter, however, changes the length of the film path between rollers G and F. This lengthening of the film path causes the loop above the pressure plate to be decreased when the film path below the pressure plate is extended, thus accelerating the film through the pressure plate. As the interrupter rotates, however, it leaves the film, causing an excessive loop to be formed below the pressure plate. While this loop is being consumed, there is no movement of the 5-in. strip of film held firmly by the constant force exerted on it by the pressure plate. The rotating-disk shutters are geared with the sprocket and interrupter in such a manner as to expose the film completely before it is again placed in motion. The double-roller arrangement on the interrupter causes the film in the pressure plate to stop twice for each $5\frac{1}{10}$ in. of film supplied by the sprocket. The shutters, however, are so arranged as to expose the film only once for each complete rotation of the sprocket and interrupter when taking 5-in. pictures. This shutter is replaced by another having double openings, and a mask is inserted in the aperture for taking $2\frac{1}{2}$-in. pictures. In this manner the frame size is reduced from 5 in. to $2\frac{1}{2}$ in. in length and the camera produces pictures at twice the 5-in. frame rate while rotating at the same speed.

The shutter system is composed of two $9\frac{1}{2}$-in. diameter disks, both of which rotate in the same direction. The shutter closest to the film plane serves to expose the film and is geared to make four complete revolutions for each $5\frac{1}{10}$ in. of film fed by the sprocket. This provides a high traversing speed resulting in a short time increment between the top and the bottom of the 5-in. aperture. This exposing disk has one 21° opening. To prevent the film's being exposed four times, another

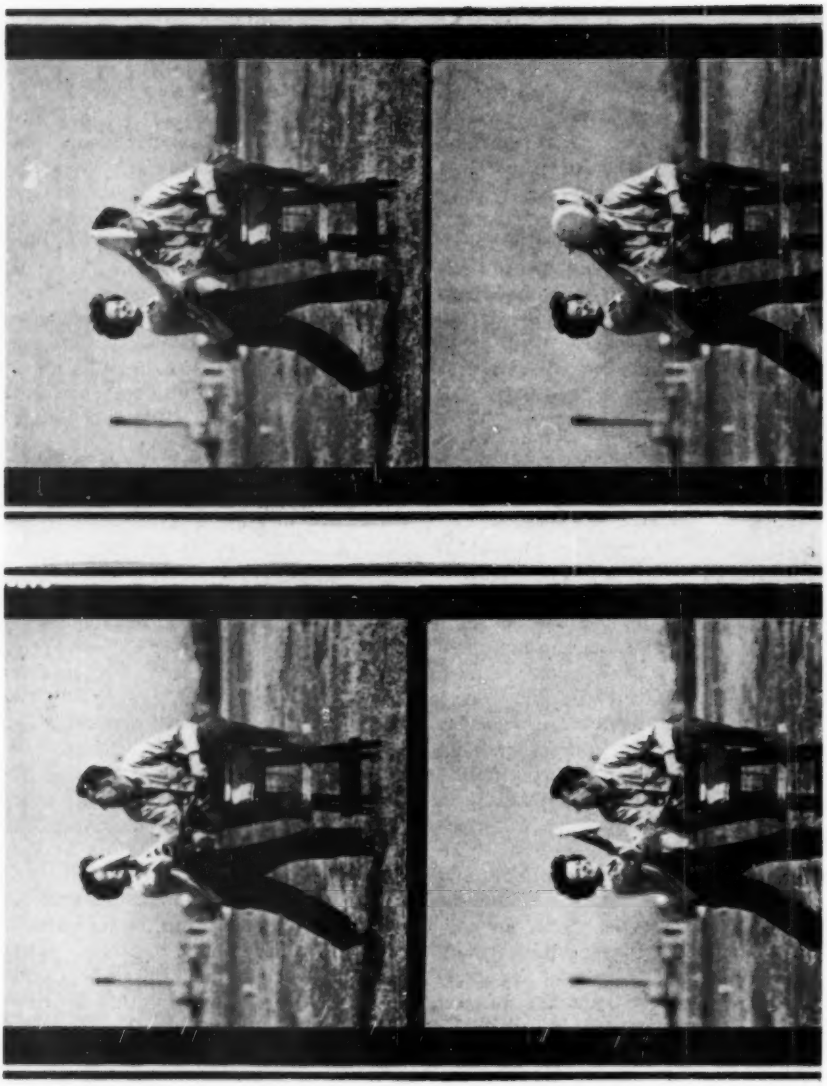

Fig. 3. Contact prints of a sequence taken at 45 frames/sec.

Fig. 4. Phases of a *tour jeté* from a ballet sequence taken at 40 frames/sec.

shutter having one 90° opening rotates directly in front of the exposing shutter and at one-fourth the speed of the exposing shutter. This masking shutter, therefore, prevents film exposure for all but one of the four revolutions made by the exposing shutter. Both shutters are aligned with the interrupter in such a manner as to provide exposure of the 5-in. film strip only while the film is motionless. The exposing shutter was purposely designed with a fixed opening in the interest of simplicity and to lessen the chances of malfunctioning which may arise with an adjustable opening. Since the exposing shutter, however, consists primarily of a simple flat disk, other disks with different openings may easily be substituted. Although the size and arrangement of the interrupter have been designed to stop the film for a minimum interval, it is, nevertheless, possible to increase the opening in the exposing shutter up to 70° and still obtain exposures before the film is again in motion. Exposure time in seconds is calculated as follows:

$$\frac{\text{Shutter opening degrees}}{360} \times \frac{1}{\text{5-in. frames/sec} \times 4} = \text{Exposure time in seconds.}$$

To change from 5-in. to $2\frac{1}{2}$-in. pictures, the masking shutter with one 90° opening is removed and replaced by a similar shutter having two diametrically opposite 90° openings. This masking shutter is keyed to the shaft in the same position as the 5-in. frame masking shutter. Since the interrupter stops the film twice for each $5\frac{1}{16}$ in. of film supplied for each revolution, the double opening shutter allows the exposing shutter to make exposures twice for each revolution of the interrupter. A mask having an opening $2\frac{1}{2}$ in. high is slipped into the grooves provided in the aperture. In this manner, $2\frac{1}{2}$-in. pictures are provided at twice the sequence speed of the 5-in. pictures without increasing the speed of the camera. Inasmuch as the exposing shutter is rotating at the same speed, the film exposure remains the same for the $2\frac{1}{2}$-in. frame size as it was for the 5-in. frame size, even though the camera is taking pictures twice as fast. The 5-in. pictures are spaced approximately 0.1 in. apart and the $2\frac{1}{2}$-in. pictures approximately 0.05 in. apart, thereby resulting in a minimum film waste.

Lenses are mounted on a lens plate which slides in machined grooves on the front of the shutter housing. This housing is hinged and may be swung open to change shutters. When closed, it is locked firmly against machined surfaces and aligned by a conical ring. Lenses of from 5-in. to 40-in. focal lengths have been utilized and several installations are considering the use of considerably longer focal lengths. The $2\frac{1}{2}$ in. by $2\frac{1}{4}$ in. frame size provides $7\frac{1}{2}$ times the area of the 35mm standard frame. It is possible, therefore, to track missiles with the same accuracy as obtained with the 35mm camera with lenses of more than twice the focal length employed with 35mm cameras.

This camera is powered by a $\frac{1}{8}$-hp series motor with a variable-speed centrifugal electric governor. Its roomy interior provides adequate space for special timing devices, either within the lens mount when the timing system requires the use of the shutters, or at or near the sprocket, when the timing system requires that the film be traveling at a constant rate. When timing is inserted on the lower side of the sprocket, the film distance between the timing marks and the exposure remains constant irrespective of the size of the loop used when threading the camera, since the camera automatically fixes the lower loop.

It is believed that this camera will do much to fill the gap which has so long existed between the small frame size of the movie camera and the large frame size of the still camera.

Precision Film Editor Utilizing Nonintermittent Projection

By TORBEN JOHNKE

Maximum efficiency in editing film both in production studios and in television stations is the objective of a recently developed preview-and-editing machine which utilizes a continuous projection process in place of the customary intermittent movement and shutter. Because projection is continuous, and because all parts are so machined that no portion of the film except the sprocket-hole area ever comes into contact with any surface, valuable originals and fine-grain masters can safely be edited on this machine.

ONE IMPORTANT WAY to reduce costs of production is to minimize time lost in previewing and editing. To attain utmost economy in those two processes three requirements must be fulfilled.

First, the equipment used must be of such nature that valuable originals and masters can be entrusted to it without risk of damage. Otherwise editing and previewing must be deferred until after duplicates have been made. If production must be suspended pending previewing, the time thus lost can be of significant importance.

Second, the equipment used should be sufficiently versatile in design and details to meet all normal demands of studio and telecasting procedures without any delay for modification of facilities or special setups of any kind.

Presented on April 25, 1952, at the Society's Convention at Chicago, for R. M. Savini, by Torben Johnke, Editor Precision Equipment Corp., 130 W. 46 St., New York 36, N.Y.

Third, the equipment should permit several persons to see the picture and hear the sound simultaneously. And if the picture is bright enough for several persons to see it clearly under ordinary room lighting that is a further advantage.

The Precision Film Editor is a device engineered in every detail to meet the above requirements completely and with generous tolerances. It is versatile and flexible in operation to a degree that is unprecedented in operation; if used with only ordinary care, even by unskilled personnel, it can be trusted absolutely not to damage film; it presents a 7 × 9 in. screen image bright enough to be seen clearly under ordinary room illumination and a loudspeaker output of 4 w.

Figure 1 is a general view of the machine. At top, rear, is the screen, flanked on one side by the loudspeaker grille and on the other by a dummy grille included for, symmetry of appearance, behind which is located the amplifier.

The projector mechanism and sound-

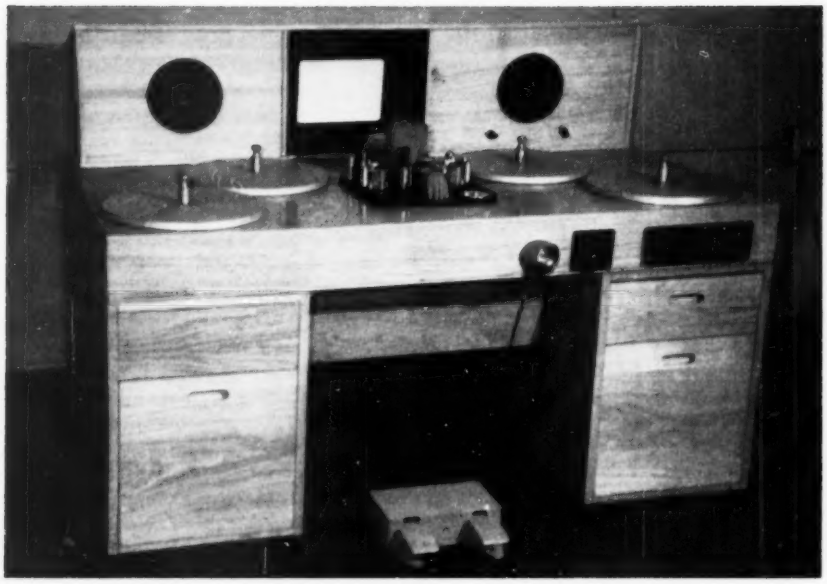

Fig. 1. The Precision Film Editor.

Fig. 2. Panel control board.

head are grouped on the panel in the center of the table, with the projector nearer the screen and the soundhead at the rear, nearer the operator's position. The two turntables at left are intended for picture and sound reels, respectively, the one nearer the screen carrying the picture film and the one nearer the operator, the sound film. The corresponding take-up turntables are at the right. However, right and left can be reversed, since motor direction can be reversed with ease.

The controls are seen, conveniently located for the right hand, on the front of the desk. The chromium control at left is for adjusting synchronism between picture and sound. The sound reel always runs at constant speed — although that speed may be varied; the chromium control is used to adjust the speed of the picture reel faster or slower with reference to the sound reel, until synchronism is attained. A frame counter shows exactly how many frames displacement were needed to achieve synchronism. At the right of the synchronization control wheel is the speed control knob. This alters the speed of both sound and picture reels simultaneously between limits of 2 and 56 frames/sec. To the right of the speed control is a row of switches for the amplifier, motor, etc., and a volume control. The foot pedals can be used instead of the hand control, if preferred, to set the equipment into operation. Pressure on the right pedal drives the films forward; pressure on the left pedal automatically disengages the forward drive and throws in reverse drive.

Figure 2 shows the panel controls in greater detail, and also shows the editing machine with separate picture film and sound film threaded in, in one of the three ways of threading.

There are two other ways of threading. When previewing or editing combined picture and sound prints, the picture film is threaded through the aperture and then run directly to the soundhead without loops. Since the projection process is continuous and an intermittent movement does not exist in this mechanism, no loops are needed; and if the film is threaded taut the displacement between picture and sound apertures is always exactly $19\frac{1}{2}$ frames. When separate picture and sound prints are used, and the purpose is to edit dialogue or perform any other function for which sound flutter is not important, the sound film can be threaded through one sprocket only instead of two for faster, easier operation.

There are two general methods of editing. In one, the editor uses the surface of the editing machine as a rewind bench, and cuts and splices the film as he proceeds. In the other, the editor makes notes which are passed on to another person who subsequently does the cutting and splicing. These notes may include information on the number of frames displacement needed for synchronism. They may also include references to the film markings made by the editor, for this machine has two film markers, one at the picture aperture and the other at the sound aperture. Figure 3 shows the latter in use. A small chip is nicked out of the film. These chips drop into containers provided for them, which must be emptied occasionally; loose chips might conceivably get into the drive and scratch film, hence these special containers which make any such occurrence impossible are provided.

The drawers at the right and left side of the machine provide reasonable storage space for film, reels, splicing materials, note pads and other facilities for efficient operation.

Figure 4 shows some of the mechanical details of the drive. The motor is wound for 220 v, 3-phase a-c, and has a built-in stepless gear for continuous variation of driving speed. In Fig. 4 we are looking at the machine as it would appear if laid over on its back; the underside of it faces us and the control panel is at the top. The chromium synchronization-control wheel is just visible at the top,

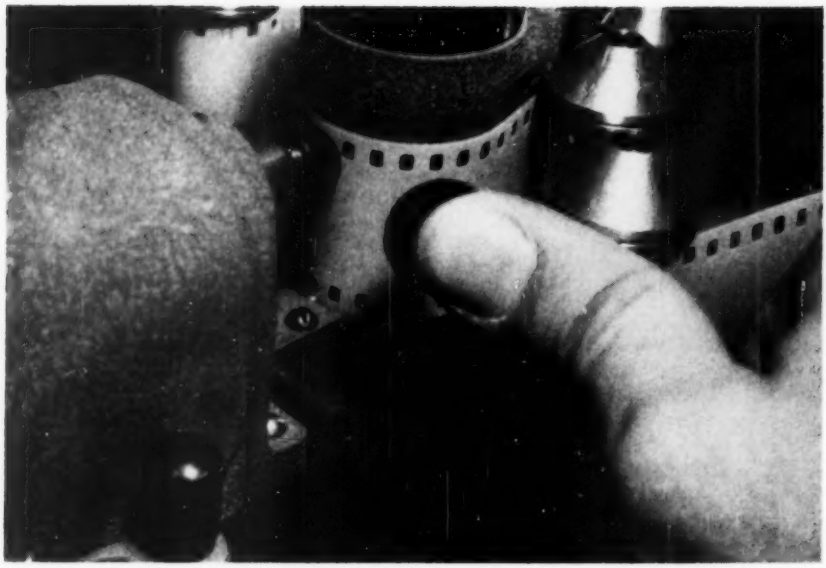

Fig. 3. Film marker at the sound aperture.

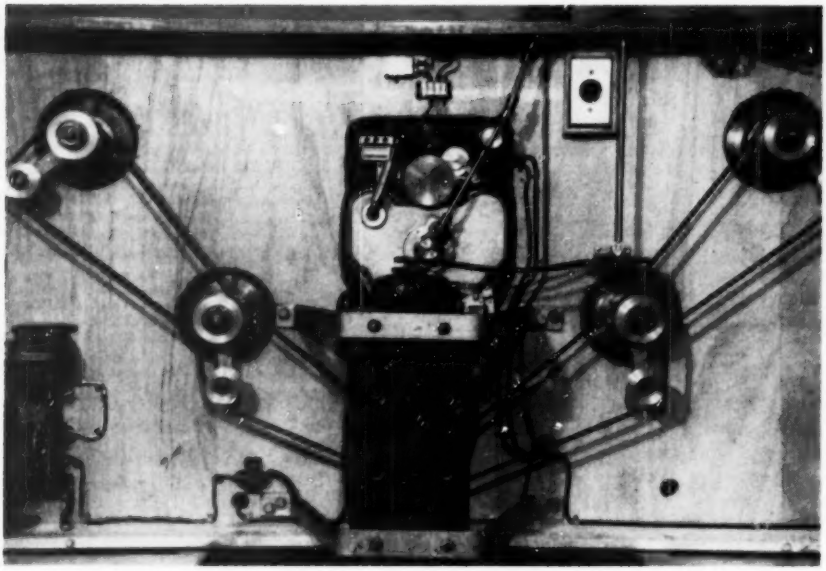

Fig. 4. Underside of machine's table, showing drive; control panel at top.

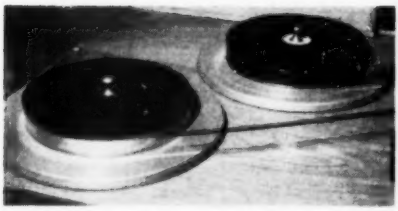

Fig. 5. Open rolls of film on machine.

Fig. 6. Film on reel on machine.

toward the right; from it a shaft with a universal joint extends diagonally downward. Just right of the synchronization-control wheel is the speed control knob; from it a shaft extends vertically downward to a sprocket; and from this sprocket a chain runs leftward to the housing of the combined motor and stepless speed control gear. The V-belt drives to the four turntables are plainly visible, and at the extreme left there is a glimpse of one of the relays that control and reverse the drive motor.

The machine can accommodate either open rolls of film, or film on reels, as shown in Figs. 5 and 6; there is no need to take time out and delay proceedings merely to put film on a reel or take it off one—it can be taken either way it comes. How this is accomplished is shown in Fig. 7, where the spindle for open rolls has been lifted off and placed to one side, revealing the spindle used when film is on a reel. Up to 2,000 ft of film in one roll or reel can be accommodated.

The heart of the Precision Film Editor is the shutterless continuous projector.

The lamp used for projection light is actually a sound exciter lamp of 10 v, 7½ amp rating. Screen illumination at 75 w is ample.

From the lamp the light path is through a condenser lens and then through the film. Film motion is, as the pictures show, lateral instead of vertical. After passing through the film the light enters and traverses a 12-side revolving prism. This prism can be described as a disk of optical glass as high as a frame is wide, rotating horizontally behind the film;

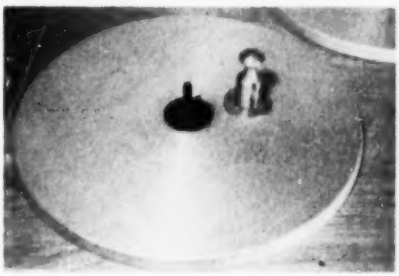

Fig. 7. Spindle for open rolls placed to one side to show spindle for film on reels.

this disk, however, is not circular, for its rim has been ground to a duodecagon. Each prism face has approximately the same dimensions as one frame; and the rate of rotation is 2 prism faces per frame in the same direction as the film.

On emerging from this rotating 12-face prism the light beam passes through the projection lens and then into an assemblage of three motionless triangular prisms. These latter perform three functions: by their agency the light beam is deflected upward; the image is erected so it will appear erect on the screen; and, finally, the light beam is deflected forward, above the top of the rotating prism housing, to the screen.

In Fig. 2 the projection lamp and condenser lens are inside the housing nearest the screen. Thence the light path is forward, through the film, toward the operator. Having passed through the film, the light proceeds to and through the rotating prism under the circular housing. On the near or left side of the

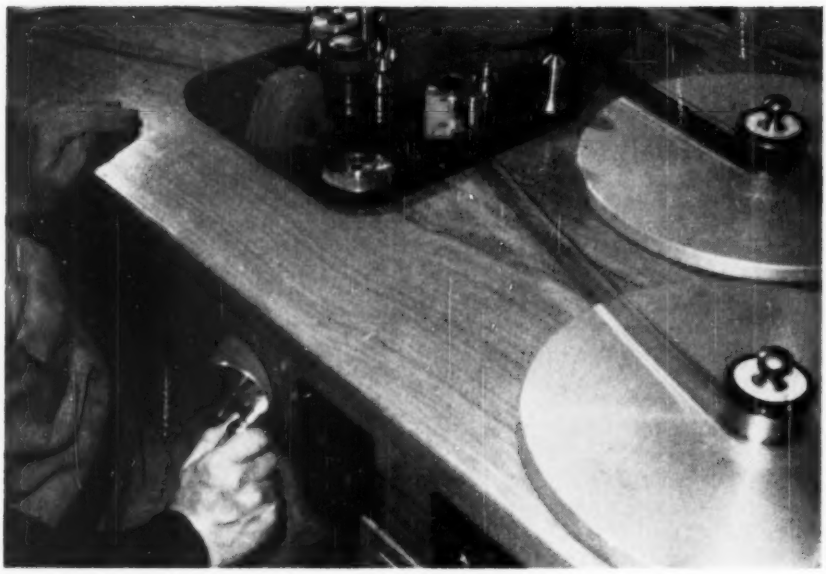

Fig. 8. Film editor in use, showing synchronization control.

circular housing can be seen the turret arrangement within which are the projection lens and three stationary, triangular prisms. From the top of this little turret the light beam is projected straight across the prism wheel and lamphouse to the screen.

In operation, this mechanism produces a screen image that is always in frame. The image is free from flicker even at the low projection speed of 2 frames/sec; successive frames appear to merge into one another. This of course is what they do, since there is no shutter.

This nonintermittent projection system needs no gate and has none. At no point in the film path does the picture area come into contact with any mechanical surface. Operation is vibrationless. At speeds up to 24 frames/sec operation is absolutely silent; at higher speeds some machine noise may become apparent.

Because projection is nonintermittent the film can be brought to full speed from a standing start within one frame without danger of damage; and it can be stopped and reversed in direction with similar rapidity without danger of damage. With intermittent projection, or with a projection gate, this would be impossible.

The soundhead in Fig. 2 is the panel assemblage closest to the operator. The curving hood at the front of the panel houses the exciting lamp. Since the film motion is lateral, this is a lamp with a vertically-disposed filament. It is of 6-v, 1-amp rating, and powered by a superaudible a-c frequency. The photoelectric cell is inside the drum just to the rear (right) of the exciting lamphousing.

The comfort of the editor or other operator has been fully considered. The foot pedals of Fig. 1 are cable-connected, and enough slack in the cable has been

provided so they can be drawn forward, out from under the machine. For example, the continuity girl might put her typewriter alongside the film editor and these foot pedals under her typing table.

Figure 8 shows the film editor in use. The operator is relaxing comfortably, with his right hand on the synchronization control. The resynchronizing frame counter can be seen clearly just to right of the exciting lamp hood; on the other side of that same hood is the footage counter and a continuous frame counter. Footage and frame counters can be reset manually to zero at any time.

The Precision Film Editor is available for 16mm as well as 35mm film, and also for $17\frac{1}{2}$mm; but not as yet for $\frac{1}{4}$-in. tape. A magnetic soundhead has been designed, and can be added to the equipment shown in these pictures. Provision has also been made for using headphones, when desired, in place of the loudspeaker so the equipment can be used in a noisy location without disturbance to others or distraction to the user.

The Bridgamatic Developing Machine

By JOSEPH A. TANNEY and EDWARD B. KRAUSE

A need was felt for a reasonably priced, quickly accessible, self-contained automatic film processor for television stations and small laboratories. This led to the design of the Bridgamatic machine which embodies standard commercial design plus a continuous overdrive, tension-relieving devices, straight-line film flow and ease of handling. 16mm and 35mm negative-positive and reversal models are described. The add-a-unit idea was adopted, so the bare machine can later be equipped with whatever refinements are desired.

THE GOAL OF SMALL FILM PRODUCTION units has long been quick processing. It has been attained by some, like the big-city television stations which telecast "spot" newsreels of the day's events the same night. Many racetracks, too, project an entire event within a few minutes after the finish. But the equipment cost has been almost prohibitive for educational institutions, small producers and commercial film studios catering to the lesser television stations.

The Bridgamatic was designed to fill this need for a compact, self-contained automatic processor. After several years of experiments, a practical, simple drive mechanism was designed which would be reasonably tamperproof and require no special skills to operate. It was planned that with intelligent handling it should keep the film moving for hours without much operator attention, other than changing reels. Exposed film was to be fed into one end so it would emerge at the other end, developed, fixed, washed, dried and reeled ready for projection or printing. This seemed at first a comparatively easy problem; but because film stretches when it is wet and again contracts when it dries there is a constant and continuous variation in its linearity. It was found that a fixed speed drive would not take care of this without manual readjustment while the machine is running. So, the overdrive system was adopted.

Presented on October 8, 1952, at the Society's Convention at Washington, D.C., by Joseph A. Tanney, who read the paper, and Edward B. Krause, S.O.S. Cinema Supply Corp., 602 W. 52 St., New York 19.

Function of the Overdrive

This equipment operates through the medium of two separate drive systems combined to produce an overdrive on the upper banks of rollers (Fig. 1), thus eliminating any troublesome drive components immersed in the solutions. The basic drive consists of a chain which is driven through a conventional gearbox and a drive motor. This in turn drives a series of chain sprockets synchro-

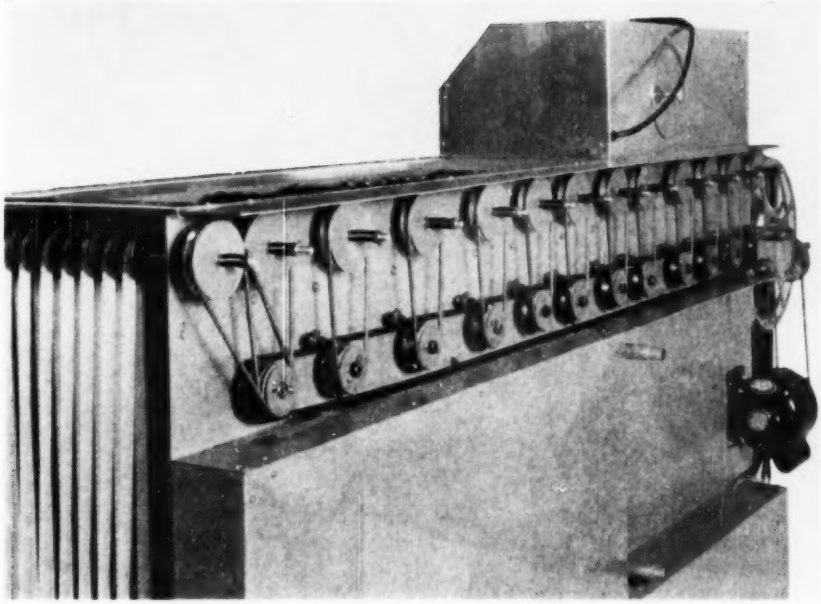

Fig. 1. Bridgamatic drive compartment with cover removed, showing individually driven phenolic yieldable clutch pulleys.

nously, one sprocket for each bank of rollers in the machine. Permanently affixed to each chain sprocket is a laminated bakelite phenolic pulley of the same diameter. This serves as a connecting medium to the secondary drive system, thus providing the means of operating the upper banks of laminated phenolic bakelite pulleys. A belt connects the upper and lower pulleys, thus making the lower synchronous pulley the actuating medium and the upper pulley the driven medium.

Attached to each upper sheave is a yieldable friction clutch. These upper driven pulleys decrease in diameter from the feed-in end of the machine through the drybox to the take-up. This tapering diameter sheave system increases the peripheral speed of, and induces an overdrive in, the upper banks of rollers, each bank rotating at a greater rate than the one behind it, and so on throughout the entire machine. The yieldable friction clutches hold the overdrive in check, and will not allow any unnecessary strain or pull on the film strands at any time. Each clutch is adjustable as to tension by a tempered compression spring held by a locking collar. Significantly enough, these springs in themselves contribute little to produce the overdrive in the Bridgamatic machine.

This overdrive is mathematically calculated when the pulleys are made — the amount of overdrive is positive for the life of the machine and has no dependency at all on critical spring pressures or other fine adjustments. Through this means of transmission it is also possible to vary the amount of overdrive at any one section of the machine. For instance, in the extremely long machines used for color processing, it is possible to eliminate

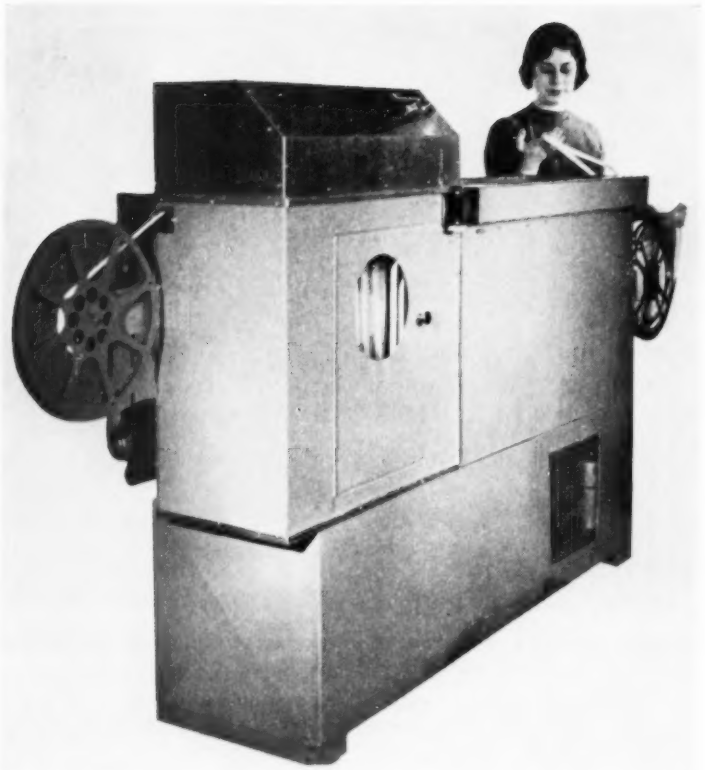

Fig. 2. Operator inspecting film before making quick splice while machine is still running.

completely the overdriving tendency in the drybox where the film is contracting while it is drying. In the usual types of Bridgamatic machines for small laboratory use, the overdrive is carried through from the film entry point right to the take-up reel. Even the film in the drybox has an overdrive working there which is also controlled by the yieldable clutches. The springs on the clutches are merely sufficient to place the upper banks of rollers in operation and the overdrive automatically takes over from there. This action takes place continuously in all sections of the machine, even though the movement is normally imperceptible.

Adjusting the Overdrive

Each individual bank or group of rollers is adjustable to tension by releasing the locking collar setscrew using an Allen wrench and compressing or releasing the spring as necessary. An overall adjustment can be made quite easily and simply. The film is hand held at the feed-in end and the machine is started. Each bank of rollers will in turn automatically stop rotating. The film is then released and the rollers are observed as they resume driving. Each bank should start successively without hesitation the moment the tension is released. The first should start, then the second, and so on, until

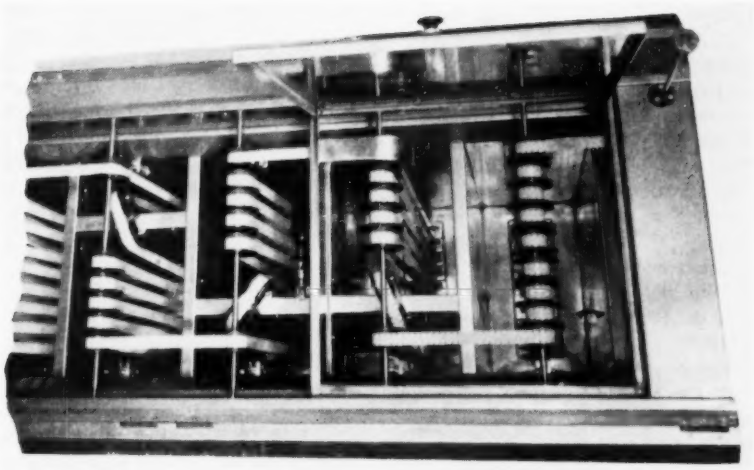

Fig. 3. Interior of stainless-steel tanks showing nylon bearings, stainless-steel shafts and other parts of inert materials.

the take-up reel is turning and the entire machine is in operation. If there is any lagging, the cycle is repeated to locate the offending bank, then the lock collar is loosened and more spring tension applied as necessary to that particular section.

When this drive system was being designed one of the requirements which seemed important was to keep the drive mechanism completely clear of any chemical contact with solutions. Another important item was to keep the machine as wide open as possible and free of complicated covers and inaccessible places. This was solved by enclosing the entire drive mechanism in a separate housing of its own (Fig. 1) where it is completely out of sight and away from solutions, tanks, etc. The entire film roller assembly can be removed from the machine in a half hour with nothing more than an Allen wrench. This provides for simple periodic cleaning of the tanks and rollers if necessary without a total breakdown of the machine with its attendant layup period.

Control of Film Transport

Tests made at the factory with this type of drive showed that it was possible to run single 8mm film through the machine without any film breakage. A splice using only one staple did not let go throughout the entire process. By alleviating the stresses and strains, this machine's drive exerts so little driving torque that it produces a very clean film product and reduces abrasion marks on the base side of the film to an absolute minimum. Test strips (or any particular section of the work going through) may easily be removed at any time, in any stage of processing. This is done by simply grasping both ends of the film to be removed, making a quick cut and stapling the loose ends (Fig. 2).

Controls and Connections

One master switch controls the entire assembly. Thus one cannot run the machine without the heater and blower in the drybox or the refrigeration system also being in operation. This prevents

film from coming out of the machine wet.

Heliarc-welded 18–8 stainless-steel insert tanks are regularly supplied together with stainless-steel film guides or grids and simplified lifts at the bottom of each tank. These keep the film on the lower banks of rollers when lifted for threading or cleaning the phenolic bearings. All parts in contact with solutions are of stainless steel or other inert materials (Fig. 3).

This equipment requires a minimum of plumbing. In the absence of permanent connections, a garden hose fits the two pipe fittings protruding from the wash tank. The lower pipe connects to the darkroom water supply and the upper pipe to the drain or sewer. This gives a circulating water supply in the wash tank. If a rapid water change is desired, a portable drain pump is useful in several ways. It will pump all solutions into and out of the tanks and act as a draw-off pump on the upper wash drain. A smaller pump, especially for overflow draw-off, is also available as optional equipment.

There are three speed-change pulleys mounted on the drive motor at the end of the standard machine: small for negative processing, intermediate for sound-track processing and large for positive film processing. A recently announced optional feature is a 10 to 1 ratio variable speed control transmission which permits an unlimited range of developing times from 2 min to 20 min. This entirely enclosed assembly is integral with the main drive motor, and replaces the step pulleys with their three fixed speeds. A variety of formulas can, of course, be used and the raw stock suppliers can provide suitable developing and fixing mixtures. Additional formulas can also be found in the Photo Lab Index.* The average developing times are 6 to 7 min for negative, 5 min for sound track and 2 to $2\frac{3}{4}$ min for positive film. Raising solution temperatures to an average of 90 F decreases the developing-time cycle, and increases the machine's output considerably. An immersion heater for the water jacket with thermostatic control and an extra Calrod strip heater in the drybox can be installed as original equipment, or added later.

A special Bridgamatic high-speed Reversal 16mm machine to process at 100 fpm is also available. It is designed for ultra linear operation with but 100 ft of leader in the machine and it allows 200 ft of picture to be completely processed in 3 min. It operates at 125 F using a pressurized spray and the latest principles embodying rapid drum-type drying. The machine can be designed to exit the film head or tail first, whichever is desired. This unit is entirely automatic, including thermostats, pumps, filters and by-pass controls.

Savings Effected in Chemicals

The machine will operate with only one to two gallons of developer and produce excellent results, effecting a considerable saving in chemicals on small jobs. Normally for larger runs, quantities of $2\frac{1}{2}$ to 5 gal are used. There is a replenishment formula furnished with most developers and over long periods this should be added as instructed. Ordinary hypo formulas with hardener added are used in the third or fixing tank. Air squeegees are provided for blowing the water from the film before it enters the drying cabinet. It is necessary, of course, to have a compressor of proper capacity operating the squeegees. This must be the type that puts out oil-free air, although a filter is recommended as well.

Color Processors Also Available

The basic processing machine is of a negative-positive design with four

* *Photo Lab Index*, Morgan and Lester, Publishers, 101 Park Ave., New York 17.

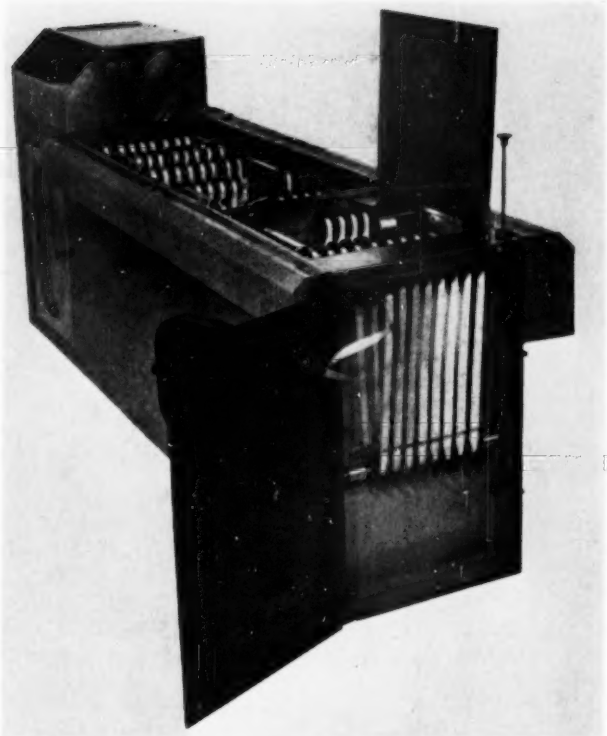

Fig. 4. Bridgamatic TV Reversal Model showing daylight magazine, feed-in elevator and light-tight cover for first three tanks.

tanks: developer, rinse, fix and wash. Microfilm models have an added wash tank with spraybars. A length of from 200 to 400 ft of leader is required, and tank capacity varies from $2\frac{1}{2}$ to 15 gal, depending on the model, whether 16mm, 16/35mm combination or 16mm reversal.

The most popular model at present is known as the Bridgamatic TV Reversal Special, a nine-tank machine measuring 8 ft long, 2 ft wide and 4 ft high, weighing 650 lb. It features a daylight loading magazine, feed-in elevator with rising indicator and buzzer alarm, take-up elevator, re-exposure lamp and two heats in the drybox (Fig. 4). Aeration or bubble agitation with a controllable valve is provided for the bleach tank, with a spray header in the final wash. Speed is rated conservatively at 750 ft/hr. The new High Speed Rapid Reversal pan films recently introduced (such as Du Pont's 931) have increased this speed approximately 50%. The machine is made for operation under average room lighting and consumes but 20 amp.

These machines are now also custom built to a variety of speeds and sizes, from 16mm to 70mm. Two new models are being built for the new Eastman Negative-Positive Color Process or Ansco Negative-Positive Color Process. It may soon no longer be necessary for the film producer to think of

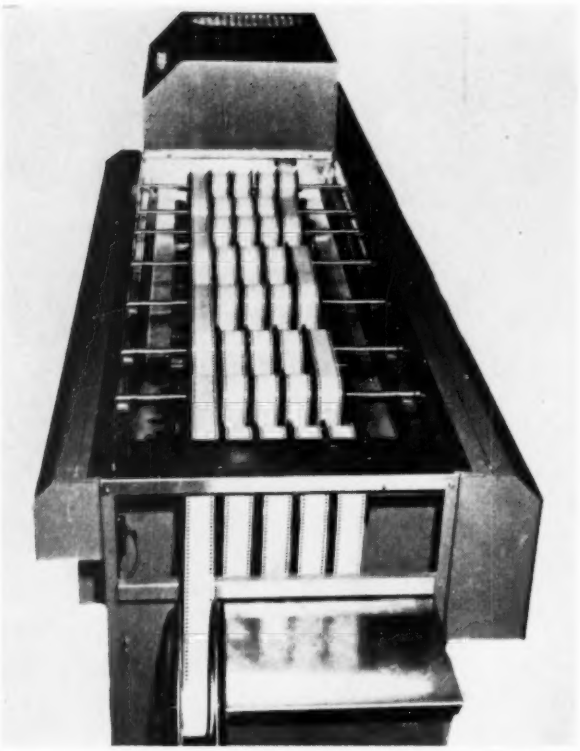

Fig. 5. Top view of Bridgamatic 16/35mm machine showing straight-line design with all major parts instantly accessible.

color in terms of outside laboratory work and expense. Heretofore color processing machines were huge, costly and cumbersome, and certainly only an investment for the largest commercial laboratories since the cost of chemicals alone was tremendous. This small, reasonably priced color processor is expected to save many times its cost in a short time as the most expedient way of processing and controlling color quality on the spot, without the delays and accelerated production costs which go with expensive retakes.

Add-a-Unit Construction

The basic Bridgamatic machine of any model with its bare essentials may be installed first. Certain attachments are required in *all* installations such as: an air compressor to activate air squeegees and supply aeration; a drain pump for changing solutions and cleaning out the tanks; air and water filters; and a film stapler with rust-resistant staples. Other recommended attachments are: recirculating pumps and filters; draw-off pumps; time-delay feed-in or take-up elevators; refrigeration with temperature controls; daylight loading magazine; sub-base to house accessories and to raise the machine to a more convenient working height; replenishment system; hydraulic speed-control system; and top overflow and bottom drain valves. All may be

purchased as original equipment or some units may be added later. Permanently affixed units which involve plumbing should be incorporated with the original machine.

The advantages of this add-a-unit arrangement are considerable, for the machine's usefulness can be expanded as the needs arise. Budgets often arbitrarily limit the amount which can be spent at one time, so breaking up the equipment into smaller components proves a distinct advantage.

Ease of Servicing

Important parts are instantly and easily accessible (Fig. 5). A complete knockdown service job can be done in a few hours right on the premises where the machine is installed. Major replacements can be made quickly, as most assemblies are standard and interchangeable. There are no expensive rigging or erection costs as the machine is shipped ready to plug in and operate. Extreme portability and comparative light weight enhance the utility of the apparatus, while the cost makes it a practical equipment for even the smallest organization seeking automatic film processing equipment.

Discussion

Bernard L. Elias (Eastman Kodak Co.): By what method or channels are the recirculated solutions dispersed within the tanks?

Mr. Krause: What we use is a stainless-steel recirculating pump and the developer is drawn down through the input end of the pump and then is pumped back in through a stainless-steel line to the tank and through stainless-steel barrels which have various size holes depending upon the solution tanks and the size of the pumps and we use impingement jets of solution below the surface of the solution itself.

Ralph Lovell (NBC, Hollywood): With this type of overdrive mechanism — is it not true that if the film stops in, let's say, the drybox, or somewhere near the end of the machine, the film in the developer end will continue to overdrive and thus produce tangled film in the developing section.

Mr. Krause: It will not allow the film to "tangle," since the overdrive will admit only enough film to break the driving traction between the driving rollers and the film itself. From that point on, the film remains in a static position until normal operation is resumed. Unless the film was deliberately held manually in the drybox, this condition could not occur.

Mr. Lovell: Also, do you have any filter in the chemical developer recirculation system?

Mr. Krause: Yes, we use the Fulflo stainless-steel filters between our tanks and our recirculating pump to filter out the small particles.

The Stereoscopic Art—A Reprint

By JOHN A. NORLING

An accelerated interest in stereoscopic photography has been inspired in recent years by the appearance of compact, well-designed cameras and viewing devices marketed at moderate prices. These new products and their increasingly widespread use support the belief that any art such as stereoscopic representation depends for popularity, indeed for survival, on the equipment available to enable people to practice the art.

THAT AN APPRECIATION and understanding of stereoscopic vision has existed for a long time is evident from Euclid's definition:

To see in relief is to receive by means of each eye the simultaneous impression of two dissimilar images of the same object.

On this definition by Euclid (280 B.C.) the entire stereo art is based. And that stereoscopic representation has long been practiced is borne out by the stereoscopic drawings of Giovanni Battista della Porta around the year 1600. How della Porta's drawings and similar drawings of other artists of that era were viewed is not known. But it is well known that the popularity of stereoscopic pictures reached a peak about 50 years ago when the stereoscope was virtually a parlor fixture. Now, although the parlor stereoscope is instead a museum piece, the art of stereoscopy appears to be flourishing again as it did half a century ago — with one principal difference: it is a participating art instead of simply a spectator art. More and more people are not only viewing three-dimensional pictures, but they are taking them with their own cameras. The popularity of stereoscopic photography looks as if it is here to stay. With a wider appreciation of its possibilities, and with an increasing number of camera enthusiasts trying their skills at stereoscopy, its possible eventual widespread acceptance as the ultimate form of photographic realism may one day come about.

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Early Viewing Devices

One of the first known viewing devices was the Wheatstone Stereoscope (Fig. 1), which was described before the Royal Society in 1838 by Sir Charles Wheatstone sixteen years after Niepce produced the first permanent photographic image. This instrument supported a pair of pictures on easels clamped to a bar, one at each end. Midway between the pictures were mirrors facing them. The observer saw the reflected images and was able to fuse them provided they were

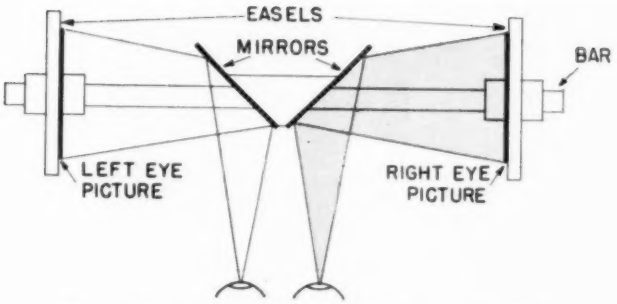


Fig. 1. Diagram of the Wheatstone Stereoscope.

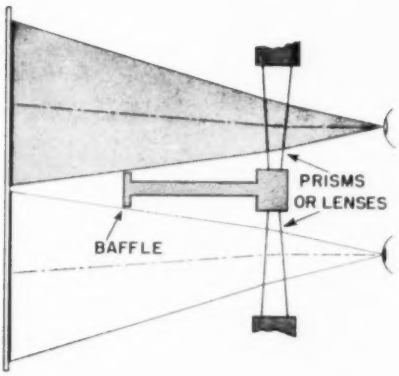


Fig. 2. Illustrating the principles of the Brewster Stereoscope. This arrangement for prisms was used for pictures whose centers were farther apart than the normal human interocular.

properly spaced and aligned. But its unwieldiness contributed to its lack of popularity.

The first practical stereoscope was invented by a Scotsman, Sir David Brewster, who introduced it in 1849 (Fig. 2). This was modified by Oliver Wendell Holmes some years later in America. In its early form, the Brewster stereoscope contained a pair of prisms which, in 1856, were replaced by segments of a convex lens. The Brewster and Holmes stereoscopes were used for viewing paper stereograms. Later, several Europeans brought out a large variety of viewers for transparencies, frequently in elaborate cabinet form (Fig. 3).

Just about the time Brewster's first stereoscope was introduced, there appeared some stereoscopic Daguerreotype portraits and novel lens-holding viewers. The accompanying illustration of one of these stereogram products is provided through the courtesy of Mr. Douglas Stapleton (Fig. 4). It is mounted in a handsome case, provided with a viewer containing a pair of convex lenses, with centers spaced $2\frac{1}{2}$ in. apart. The pictures, peculiarly enough, are spaced only 2 in. apart, introducing a little difficulty in viewing, but fusion can be attained. The name of this device is "Macher's Improved Stereoscope," patented March 8, 1853. It was made in Philadelphia.

Unfortunately, many stereoscopes had "eye-strain" as a built-in feature. Many stereograms were poor in definition and contrast, and sloppily mounted. These faults, working together, probably pro-

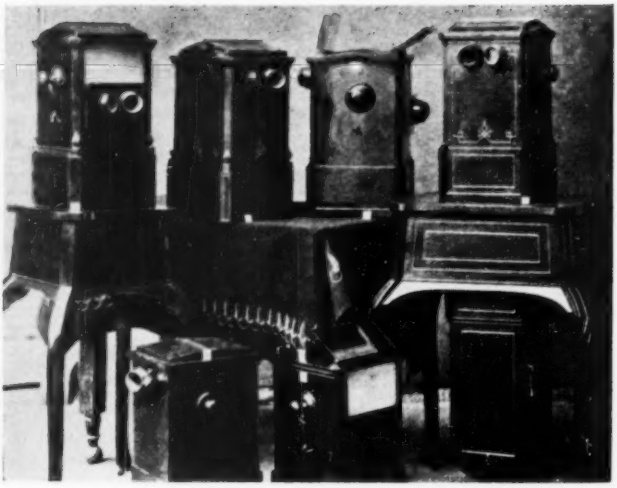


Fig. 3. A variety of early cabinet stereoscopes. *Courtesy of Robert N. Dennis.*

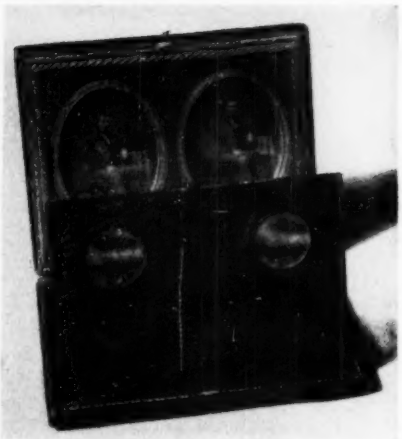


Fig. 4. A stereoscopic daguerreotype with lens stereoscope.

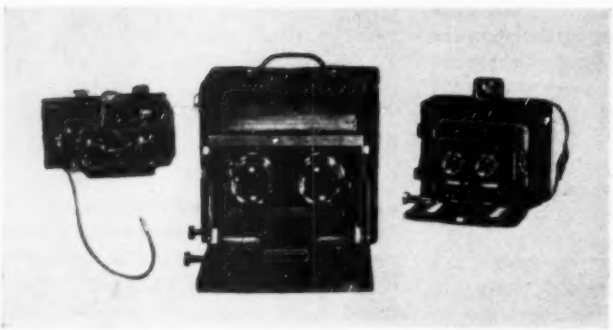


Fig. 5. Three stereoscopic still cameras. Left, Richard. Center, Stereo Graphic. Right, Ica.

vided one reason for the loss of popularity of the stereoscope.

Amateurs who still kept alive their interest in stereoscopy had to perform a number of operations not required in ordinary photography, such as the transposition and mounting of the pair of pictures. These requirements made many give up the pursuit of the art.

Oliver Wendell Holmes called a photograph "a mirror with a memory," and it was this pioneer in the art who christened the stereoscopic picture "sun sculpture." The "sculpture" in a stereogram is tenaciously remembered and details are retained that are soon forgotten in a "flat" picture.

Binocular Vision

The sensations received by the eyes are transmitted to the brain where, in a psychic assembly room, the two disparate images are fused together, so that we become conscious of relief in the view. But fusion cannot be accomplished without strain unless the two images are of exactly the same size and the "picture" axes aim at the same points. Inability to fuse exists in an eye disorder called "diplopia" in which double images are seen, and in "anesikonia," the term applied when the eyes form images of different sizes or shapes.

The Stereo Still Camera

A stereoscopic camera not having matched lenses can be said to have "anesikonia," as can projectors with unmatched lenses. If the images on the screen do not align properly, the projector has "diplopia," and the observer's eyes will have to perform acrobatic feats to attain fusion, and in the process, will suffer strain. Veracity in a stereogram exists only if it is taken properly.

Stereoscopic cameras were made in scores of styles throughout the past hundred years (Fig. 5). Among the most widely used American stereoscopic cameras was the Stereo Graphic with a focal plane shutter. It took the stereoscopic pair on a 5 × 7 in. plate.

The Europeans, principally the French and the Germans, have been very active in stereoscopy and have produced a wide range of cameras and other stereoscopic devices. A well-designed French camera was the Richard Verascope, which accommodated both plates and roll films. Separate magazines were furnished for each. The one shown as a part of Fig. 5 took the pictures on 7 × 13 cm plates; Verascopes were also made in 6 × 13 cm and 45 × 107 mm sizes. A single guillotine-type shutter operates between the elements of their two lenses. Shutter speeds up to $\frac{1}{120}$ sec were provided.

Other similar European cameras made pictures a good deal smaller than the original Richard, but some made pictures as large as $3\frac{1}{2}$ in. horizontal and $4\frac{1}{2}$ in. vertical. The German Ica contained a valuable feature usually overlooked by makers of stereoscopic cameras. This was a provision for changing the lens spacing for principal objects at different distances. The Ica's lenses move toward each other, reducing the lens interaxial when focusing on a near object, and spread farther apart when focusing on a far object. This is a feature of great importance and is discussed later in some detail. Probably, other stereo camera makers will some day make devices to provide the highly useful and often necessary varying interaxial. If it were built into the camera, there would be no necessity for using smaller slide masks that cut down the sides of the image to attain satisfactory viewing, as we find recommended practice for close-ups made by many modern cameras.

Undoubtedly, the camera most responsible for the resurrection of interest in the three-dimensional art is the Stereo Realist. This camera was the first in the modern development of the stereo art which has features that appeal to amateur photographers, particularly those who have been making color transpar-

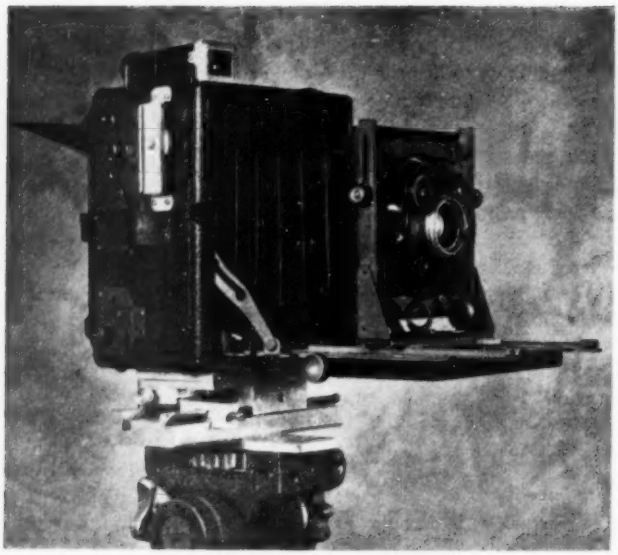


Fig. 6. Single lens camera mounted on a slide board.

encies on 35mm film. Like most popular "single-eye" miniature cameras, the Realist has coupled range-finder focusing, easy-to-learn controls, and in contrast with earlier cumbersome cameras, it fits the hand.

"Slide Board" for Stereo Still Lifes

A single lens camera can be used to make stereoscopic pictures of still life subjects by mounting one camera on a "slide board" (Figs. 6 and 7). Because only a single lens is used, both images will be of exactly the same size, and there will be none of the faults contributed by a pair of unmatched lenses. The slide board may be a simple one made of wood, but the precision provided by metal construction is much to be preferred. Slide boards can be made as long as desired, but there is little use for one that permits a camera shift of more than 3 or 4 in., except for very special purposes.

With a slide board, closeup stereograms can be made of objects so small and so enlarged, that the interaxial spacing may be only a few millimeters (Fig. 8). The slide board enormously extends the range of effects offered by stereoscopic photography, and it is an economical and convenient method for the person who would like to start in stereoscopy without first buying a two-lens camera.

Kennedy Stereo Camera

Even without a slide board, the single lens, if its aperture is large enough, can be employed to produce stereograms of excellent quality. Its usefulness seems to fall only in the still-life field, since the effective aperture employed for each image is of a rather low order. The system is simplicity itself, and was designed and built by Prof. Clarence Kennedy of Smith College, in cooperation with Dr. Edwin H. Land and Otto E. Wolff (Fig. 9). Professor Kennedy had employed it principally to obtain large stereograms of sculptures. Its diagrammatic representation shows that only a part of each lens is used for form-

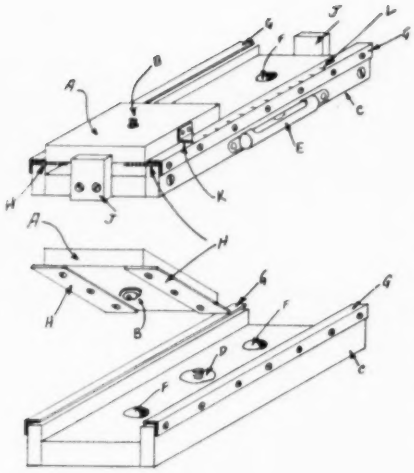


Fig. 7. A simple slide board: A, sliding member; B, camera screw ($\frac{1}{4}$–20); C, main body; D, bushing for tripod screw; E, spirit level; F, holes to clear screw driver so camera may be attached to A from below; G, angle brass; H, brass strip; J, stops; K, pointer; L, scale (paper or cloth tape).

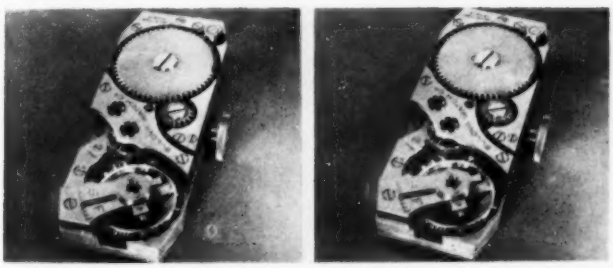


Fig. 8. Stereogram of a watch movement (lens interaxial 5 mm).

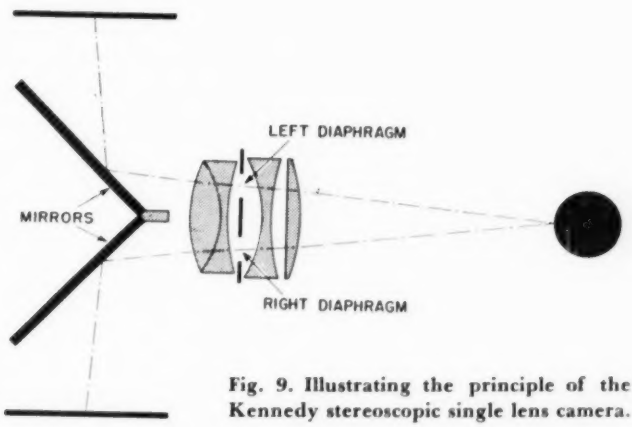


Fig. 9. Illustrating the principle of the Kennedy stereoscopic single lens camera.

ing each member of the stereoscopic pair. If the lens has a large enough diameter to accommodate the desired result, the two individual lens "stops" can be separated to the required spacing called for by the geometry of the stereogram's planned use. A lens of large diameter, 75 mm or more, must be used. Its focal length is determined by the type of stereograms to be made. A large diameter demands a lens of long focal length. Consequently, this particular process is limited to still stereograms. Because of the large size of many stereograms used this way, projection would introduce many problems. Viewing boxes are used instead.

Stereographic Drawings and Paintings

A more or less obscure form of the 3-D art is the rendering of stereographic drawings and paintings. As a teaching aid, Prof. John T. Rule of the Massachusetts Institute of Technology has introduced such novel drawings for celestial navigation and solid geometry (Fig. 10). They provide the student an unusually effective portrayal of spatial relationships. Some of Prof. Rule's drawings have been published in vectograph form as an adjunct to classroom texts. The vectograph method is discussed later in this article.

In the illustration field, Paul H. Stone has produced a number of striking stereograms. With his kind permission, we are able to publish one of his remarkable creations which he has entitled "Clinical Study of How Stereo Registers to the Brain" (Fig. 11). Mr. Stone has a theory which makes interesting reading on the subject of how the eyes work:

"Our two eyes scan every pin-point of a scene, as rapidly as a television beam; from top to bottom, side to side, and, most important, from near to far. It is less the focus of each cornea than the convergence of the two beams of vision which telegraphs a sense of depth, of distance to the brain.

"I believe the actual muscular pull on the eyeballs, whether they are crossed toward each other or straightened to parallel, and infinity, is the recording device which informs the brain about the length of the convergent triangle. Hence the brain can infer with reasonable accuracy, depths, from a few inches to the better part of a mile."

Versatile Stereo Camera

While the amateur has available a wide selection of stereoscopic cameras and accessories, there are no well-designed cameras for the professional. If he wants to go into stereoscopy, virtually the only thing he can find is an old Stereo Graphic in a second hand store, or if he is fortunate, one of the excellent Icas. But neither of these has all the features required by the serious worker.

A professional stereoscopic camera should contain, as principal features, a means for varying the lens interaxial and a means for converging the picture axes on any desired plane.

Probably the easiest way to show what a versatile stereoscopic camera is like is to describe one of several types designed by the author (Figs. 12, 13a and 13b). The diagram shows the plan view layout. The assembly comprises two camera bodies mounted on a common base. Each has its own lens, but the lenses are mounted in a unique way, pointing off at right angles, one to the left, the other to the right. In front of each lens is a first surface mirror whose face is 45° to the lens axis. A righthand–lefthand screw provides a means for moving the camera bodies together or apart, thus controlling the interaxial spacing. This spacing can be varied from $1\frac{1}{2}$ to 6 in., permitting satisfactory setting for objects as close as $4\frac{1}{2}$ ft, using 7-in. lenses. The assemblies which carry the lenses and front mirrors are moveable for a small distance forward and backward. This makes it possible to converge the picture axes to any plane desired. The images are framed within metal masks which are mounted so they can retract for the

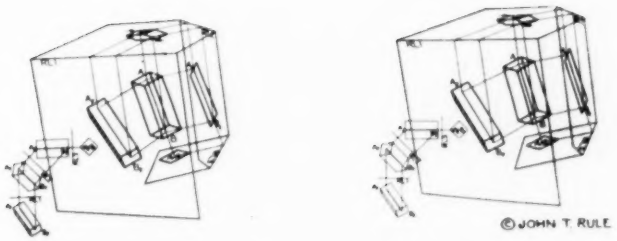


Fig. 10. A stereographic drawing illustrating a geometrical problem. *Courtesy Prof. John T. Rule.*

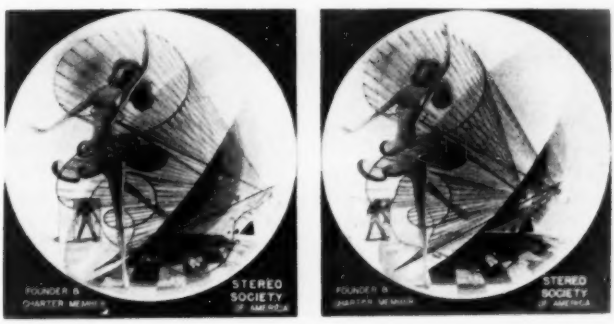


Fig. 11. Stereoscopic painting. *Courtesy Paul H. Stone.*

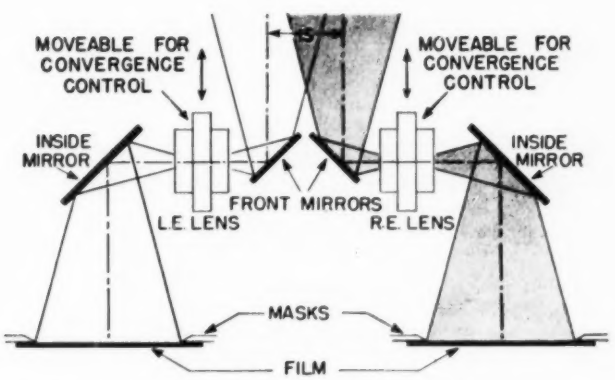


Fig. 12. Diagram illustrating the arrangement of components of a special still picture stereoscopic camera.

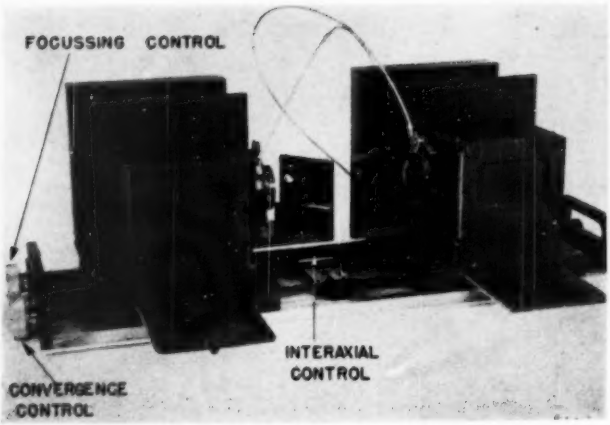


Fig. 13a. A versatile still stereoscopic camera, one of several designed by the author.

insertion of the film holder's dark slide. These masks accurately define the picture areas, and if the convergence control is properly used, the masked margins provide precise registration for mounting. It should be emphasized that precise alignment of the pictures is an absolute requirement for projected stereograms. If not precisely aligned, the 3-D pictures cannot be viewed with complete visual comfort, and the goal of the serious workers is and should be nothing short of complete visual comfort in viewing.

The mask on the right has a small hole close to the picture area that permits a cue mark for the purpose of quickly identifying it, thus facilitating the assembly of the pairs. This camera is used mostly for making color 3-D slides, although it has been used to make master black-and-white negatives for vectographs and anaglyph stereograms.

One arrangement that can be employed to attain the variable interaxial feature is illustrated in Fig. 14. In this arrangement a partially reflective, partially transmittive mirror is used, one camera being placed behind the mirror, the other being placed so that it receives the image by reflection from the partially silvered first surface of the mirror.

This method permits the interaxial to be varied from zero to the limit permitted by the size of the mirror. Of course, the "left eye" camera (in the arrangement shown) will have its image reversed left for right, but that is unimportant because the negative can be turned back to normal in printing.

The mirrors should be the pellicle type, such as are used in some color-separation still cameras. Satisfactory results have been obtained with thin glass mirrors, $\frac{1}{32}$ in. thick or thereabouts. A thick glass mirror cannot be used because a second reflection will show in the image picked up by the mirror. If a thin glass mirror is used, the secondary reflection will not be separated far enough from the primary image to become discernible if the mirror is mounted at about 57°, as shown in the diagram.

If a pellicle mirror is used it must be mounted in a frame that will afford the facility for stretching it taut.

Taking Stereo Still Pictures

The stereo still photographer is confronted with just about the same problems as the conventional still photographer, plus a few extra problems that

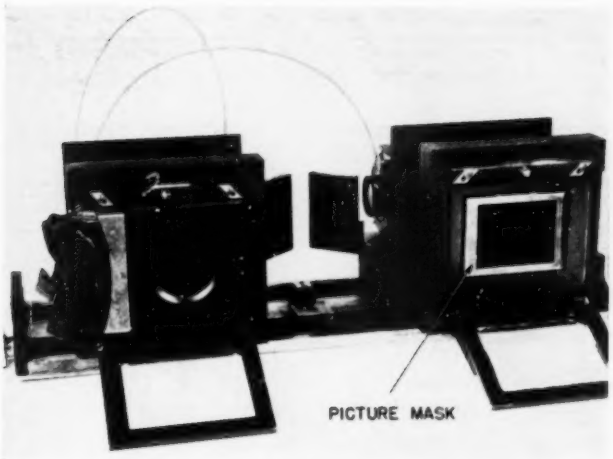


Fig. 13b. Rear view of camera showing the picture mask.

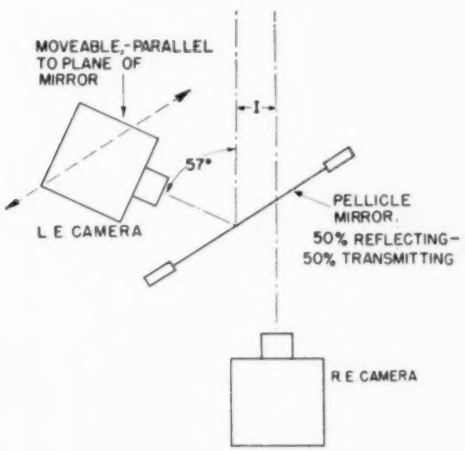


Fig. 14. Illustrating an arrangement that provides a variable lens interaxial using a partially transmitting pellicle mirror.

are peculiar to stereo. Interocular distances, interaxial distances and convergence problems are some of the extras which lie only in the province of stereo. But they are soon mastered and the pleasure derived from their mastery is rewarding indeed.

A difference in focal length between the lenses of a stereo camera of more than 0.5% will produce images differing enough in size to cause eyestrain when pictures are projected.

If glass filters are used on the lenses, there may be enough "wedging" in the filter assembly to throw the picture axes out of line. This is not serious if the misalignment is along the horizontal, but it may be significant if it is along the vertical, and when the pictures are projected, it may be found that they have disturbing

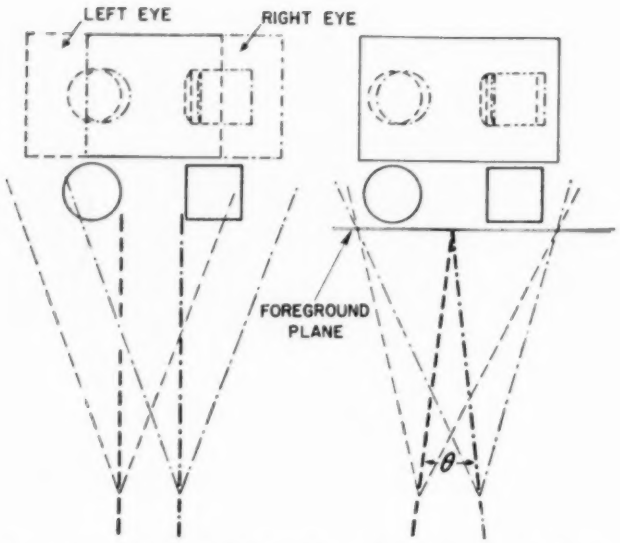


Fig. 15. Left, the side margin effect with nonconvergent lenses. Right, the effect with lenses converging on a foreground plane.

vertical displacement between them. This "vertical" may not produce a vivid consciousness of eyestrain, but it may very well produce enough effect to tire the observer after a time. As J. M. Dalzell has said, "Any sensation of visual lassitude, discomfort or even slight pain, is a psychological and mental affair. It is the penalty for exceeding certain geometric limitations which Nature has imposed upon the use of two eyes simultaneously. Its cause is cumulative and lies in the breaking — of one or more of a few exceedingly simple rules."

To avoid eyestrain, all elements in every plane must have crisp definition such as good eyes provide in their wanderings from plane to plane when looking at a scene. Out-of-focus or "soft focus" areas, whether in foreground or background, are an abomination that prevents visual comfort in viewing the stereogram.

Since the normal $2\frac{1}{2}$-in. lens interocular ordinarily should be used on objects no closer than about 10 ft, it is apparent that a properly made stereogram can be taken only in a camera having a variable interaxial. Of course, some shots may benefit from a larger interaxial than normal, particularly in cases where an increased depth is considered a dramatic embellishment. By increasing the interaxial to several times normal, the depth of such stereograms can be startlingly exaggerated.

The variable convergence feature is a "must" on any versatile stereoscopic camera because it permits the arrangement of each picture within the desired area. To be able to converge to any plane, preferably in front of the nearest object, eliminates the marginal disturbances that occur when the lens axes are parallel (Figs. 15 and 16). Such marginal disturbances are particularly annoying when they exist in the projected stereogram. The ideal stereogram should be a "real-life" view as seen through a window. Therefore, no ob-

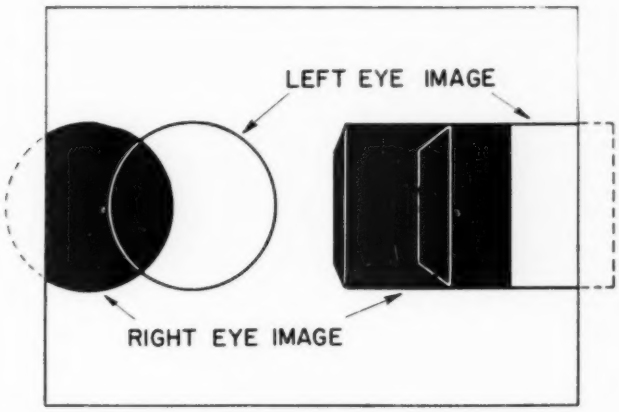


Fig. 16. Illustrating how nearby object images are cut off when image axes do not converge on objects.

ject should be permitted to invade the plane where the window exists if that object "touches" any part of the window frame. If it does, the result is a distracting border which gives non-coincidental image reconstitution.

If the "window" is at infinity, as it will be with parallel lens axes, the illusion will be that foreground middle distance and part of the far distance planes are between the window and the observer, a totally abnormal effect.

To create a proper window illusion the masks framing the images must be identically alike in shape and size and their horizontal margins must be level.

Masks can be of any shape. For instance a keyhole mask will provide a stereoscopic view through a keyhole, an anomalous effect since keyholes are so small that real-life peering through one is limited to one eye.

Where objects do not touch the window frame (the picture margins), they can be permitted to come through the window and even made to seem suspended in space between the screen and the observer. In table-top photography, one can produce this effect by mounting the subject on glass, being sure it is well inside the picture area and not touching its margins at any point. Convergence is made to occur behind the subject. Viewing comfort is then readily achieved.

Convergence is best accomplished by moving the lenses, not by "toeing-in" the camera bodies. Toe-in introduces a "keystone" distortion that makes the right edge of the left-eye picture shorter than the left edge, and the left edge of the right-eye picture shorter than its right edge (Fig. 17). This kind of distortion may not be considered important, and will be tolerated by some people, but it is one of the things to be avoided if the stereo worker wants to insure that his projected stereograms provide complete visual comfort.

To make a satisfactory stereoscopic picture, the camera must be level and to project the images successfully, there must be no vertical displacement between them and they should not "rotate" one with the other. In other words, the angular alignment has to be the same for both members of the pair.

We may work our interaxial problem out by "rule of thumb." Stereograms that are perfectly acceptable, if properly framed in projection, can be made by taking pictures only of objects further than 50 times the interaxial employed.

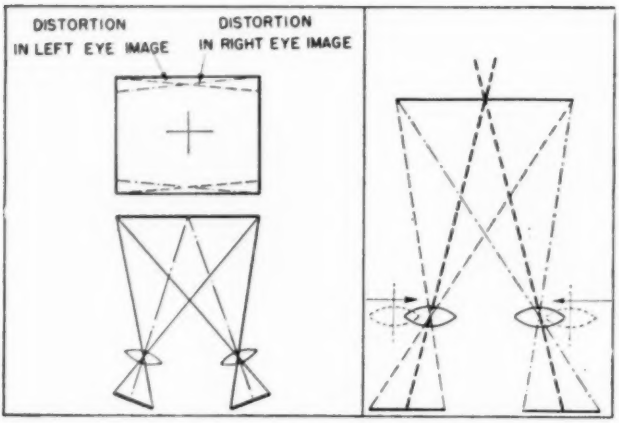


Fig. 17. Left, the distortion resulting from the "toe-in" of camera lenses. Right, a method of convergence to overcome distortion.

(This is for camera lenses of the medium angle usually employed.) This rule limits the nearest object to a distance of 10 ft with an interaxial of $2\frac{1}{2}$ in. It is violated to an extreme if $2\frac{1}{2}$ in. is used for a 5-ft distant object, where the indicated interaxial is $1\frac{1}{4}$ in.

Modern Viewing and Projection

Bringing out a modern camera for 3-D use was not enough to stimulate the rebirth of interest in the stereoscopic art. There had to be some device enabling people to see the 3-D picture. The manufacturer of the Stereo-Realist appreciated this from the outset, and accordingly brought out an individual viewer. Similar camera-viewer combinations have appeared since the Realist made its debut. But an individual viewing device is hampered by an obvious shortcoming; it limits the pleasure of looking at a 3-D picture to one person at a time. This shortcoming does not apply, however, to projected stereo pictures. Shortly after the introduction of camera-viewer combinations, a 3-D projector became available and it enables many people at the same time to see and enjoy the same stereo pictures. There are now several stereoscopic slide projectors on the market, all more or less alike.

In addition to the added enjoyment it provides, the projection of stereograms to fill a large screen does one more thing that the individual and personal stereoscope never can accomplish, and that is to create the feeling that the scene is big. While it is perfectly true that the picture on the screen may be of the same angle of view as the same picture mounted in a stereoscope, and that theoretically there should be no physical reason why the scene elements should not appear the same in each, looking through a stereoscope very often gives one the feeling that he is looking at a miniature, and he has that feeling whether or not the scene was photographed normally. Perhaps the fact that the picture is itself small in dimension gives rise to the feeling that the original scene must likewise be small.

Most stereograms made today are in the form of slides which are looked at through a hand-held viewer or seen as projected images. The hand-held, self-illuminated viewer is a familiar device. Some viewers, including the Realist, have provision for a variable lens spac-

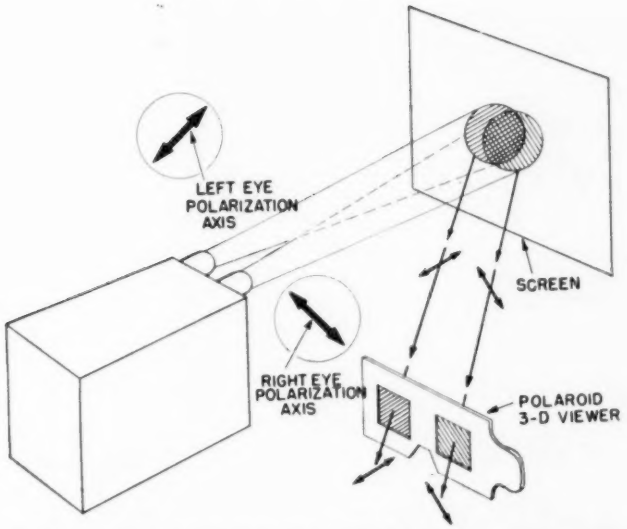


Fig. 18. Illustrating the principle of polarized light stereoscopic projection.

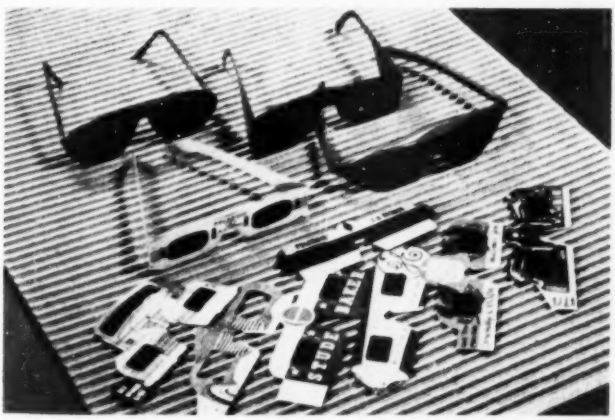


Fig. 19. Various types of Polaroid 3-D viewers.

ing — a valuable feature that contributes to visual comfort. The Stereo-Realist image is $\frac{7}{8}$ in. wide and $\frac{15}{16}$ in. high, but there are other mask sizes such as 1 in. wide by $\frac{7}{8}$ in. high, and $1\frac{1}{8}$ in. wide by $\frac{15}{16}$ in. high. All can be mounted in the standard $1\frac{5}{8} \times 4$ in. glass, which will go into the slide carriers of the new stereoscopic projectors. For professional type slides, each member of the stereo pair is made up in standard $3\frac{1}{4} \times 4$ in. glass, and put into a holder which accommodates the two members side by side.

Projection of stereo slides requires the use of polarizing filters, one for each lens, an aluminum-surfaced screen, and polarizing 3-D viewers (Figs. 18 and 19).

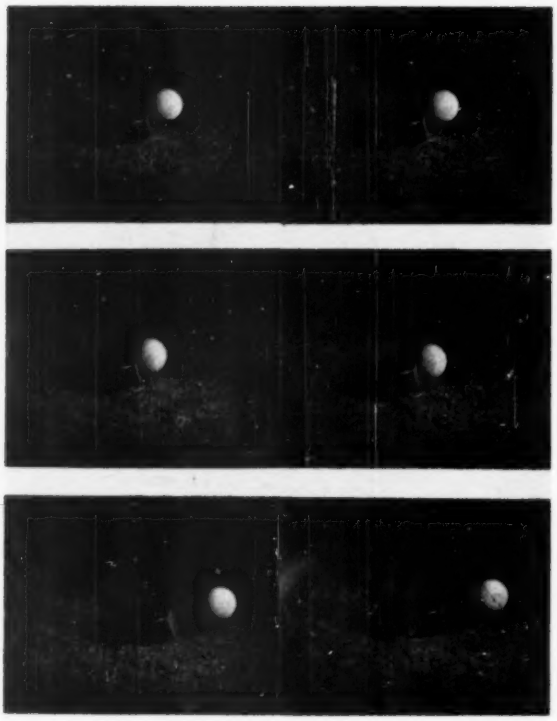


Fig. 20. Stereoscopic views made by high-speed flash, 1 μsec exposure at *f*/9 in Ektachrome.

The projection filters are arranged with their polarization axes slanting 45° from the vertical, one slanting to the right, the other to the left. The viewers have polarizing filters which also "slant" in the same manner. Consider the light from the righthand lens, with a polarization axis slanting toward the left. The light reflected from the screen can be seen through only the right-eye polarizing filter, because it too has the same left-hand slant while the left-eye filter has a righthand slant, 90° from that of its mate. Thus the "right-eye" light is blocked from reaching the left eye, and the "left-eye" light is blocked from reaching the right eye.

The reason for using an aluminum-surfaced screen is that this type of surface will not disturb the polarization of the light. A fabric or glass-beaded screen will cause the polarization to disappear, the light to become ordinary light again. The result is that the two images will be seen by both eyes, and will look jumbled like a double exposure.

Plastic screens are now available for rear projection of polarized light stereograms. Rear projection adds a brilliant quality quite different from the reflection method, although a "hot spot" may be disturbingly apparent unless arrangements are made to keep the spectator's eyes and the projection axis from lining up.

For extremely dramatic stereogram presentations, a picture 18 in. wide can be thrown by a projector containing two 1200-w bulbs and a pair of 18-in. *f*/3.8 lenses. With a picture this wide, an audience is usually given to "oh-ing" and "ah-ing" with delight and surprise as each successive stereogram appears on the screen.

Hyperstereoscopy

Hyperstereoscopy is the term applied when an interaxial base several times normal is used. It has often been employed in mountain photography and serves admirably to reveal distant details in relief. The base employed is often 100 yd or more. Care must be taken not to include any foreground, otherwise one image will contain elements not present in the other, and it will be impossible properly to fuse the stereogram. Since mountains can usually be depended upon to stand still for a long time, there is time to set up the camera and to transport it from one extreme of the interaxial base to the other. But clouds are not so considerate in "staying put" as mountains, so the exposures should be made on a cloudless day.

Hyperstereograms, properly made, require that certain rules for determining the interaxial be followed. The simplest one is

$$\frac{d \times D}{D - d} \div 50$$

where d is the distance to the nearest object, D the distance to the farthest and 50 the divisor whose use assures success.

Keeping within the limits prescribed will give the stereograms the most vivid relief possible without eyestrain in viewing.

Hyperstereoscopy has been employed to make stereograms of bodies in the solar system where even the mean diameter of the earth often proves insufficient as an interaxial base. Stereograms of most planets have been made and interesting data has thus been obtained. Included has been the discovery of a planetoid, which was found as the result of this type of stereoscopic survey, and it was appropriately named Stereoscopia in tribute to the method. Stereograms of the moon have been made which reveal intimate details of its craters and seas. Some of the most remarkable have been those of Saturn and its rings, one pair of which required the movement of Earth through space that was the equivalent of an interaxial base of about 1,000,000 miles, which is the distance traversed by our planet in its orbit during a 24-hr period. Other stereograms of this planet made with an even greater base disclosed clearly the separation of its unusual rings one from another and from the planet.

A word of warning concerning hyperstereoscopy: it does not seem to produce satisfactory results for close-up objects, and certainly will not do so if such stereograms are projected. This is so for close objects because the angle formed between the two lenses at the base and the object is so great that it throws distortion into the images. For instance, photographing a golf ball at a distance of one foot and using a wide interaxial will produce a stereogram which makes the golf ball appear egg shaped, and golf balls having this shape give neither the player nor the viewer any pleasure (Fig. 20).

High-speed stereoscopic photography is often employed for special purposes. Such stereograms often reveal things not readily apparent in a flat picture. They are particularly useful in the study of machine elements in motion and for other kinds of research. A series of three high-speed "strobe" shots were made for United States Rubber Company to prove the behavior of a golf ball. The illustrations show the impact of the club head, the "flattening-out" of the ball before leaving the tee, and the ball in its flight a few inches ahead of the club. These shots were made on Ektachrome film at a speed of one-millionth of a second, using one of Prof. Harold E. Edgerton's newer flash units. Prof. Edgerton and Henry Lester worked together in obtaining these shots. The projected pictures showed no "egg-shape" distortion which would have resulted if an interaxial larger than called for by the object distance had been employed.

No graphic means, besides the stereogram, can substitute for the re-creation

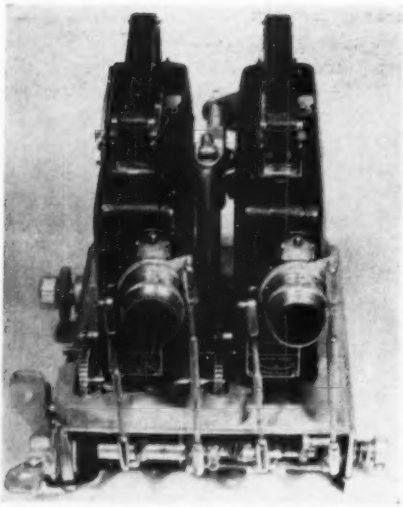


Fig. 21. Interlocked 16mm cameras for stereoscopic photography. *Courtesy Carl Breer.*

of the "real" in a still-life, and in stereo movies realism reaches the ultimate, for they can include movement, color, and action as well as depth.

The principles employed in photographing and projecting stereoscopic slides also apply to stereoscopic motion pictures. The same fundamental requirement that each eye sees only the picture intended for it also applies to the moving stereogram.

Stereoscopic Motion Pictures for the Amateur

The experimentally inclined camera enthusiast will get a lot of thrills in making and projecting stereoscopic movies. Some have done it, others are planning to enter this new field. To encourage those who are thinking about it, I shall cite the experiences of one avid fan, Carl Breer, Vice-President and Director of Research of Chrysler Corp. He has kindly provided the accompanying photographs illustrating his camera and projector arrangements.

His first camera hook-up consisted of two 16mm Magazine Cine-Kodaks, mounted so their lens axes could converge on any desired plane (Fig. 21). He selected Magazine Cine-Kodaks because they were the most adaptable at that time (1940) for mounting at the normal $2\frac{1}{2}$-in. interaxial. Since this camera arrangement requires two strips of film, he found it necessary to rig up interlocked projectors to show his pictures. Accordingly, he selected two Bell & Howell 16mm projectors and interlocked them mechanically (Fig. 22).

Carl Breer has had a lot of fun with his stereoscopic motion pictures, not only in taking pictures and exhibiting them to his family and friends, but also in devising the ways and means.

35mm Stereoscopic Motion Pictures

It seems incredible to many of us who have worked with 3-D pictures that the vast motion picture industry does not have an extensive stereoscopic research, engineering and development program. Occasionally, at the meetings of the Society of Motion Picture and Television Engineers, the subject of 3-D motion pictures is introduced. There is usually a remarkable response from the members present, and also from the press.

The art of stereoscopy has "sex appeal" but it seems to have excaped the concentrated attention of most of the people in the Hollywood area. The men in the drivers' seats of the movie industry have, for the most part, failed to have a vital personal interest in and understanding of 3-D movies. That the industry could use something to combat television's capture of more and more of the theater audience is undeniable. Stereo movies might well induce people to return to their former favorite amusement. But the return is likely to come about in the mass only if the film theater gives them something they can't get on a 17-in. television tube, namely the ultimate in photographic realism, the stereoscopic movie in full color, with all the dramatic possibilities that are only waiting to be

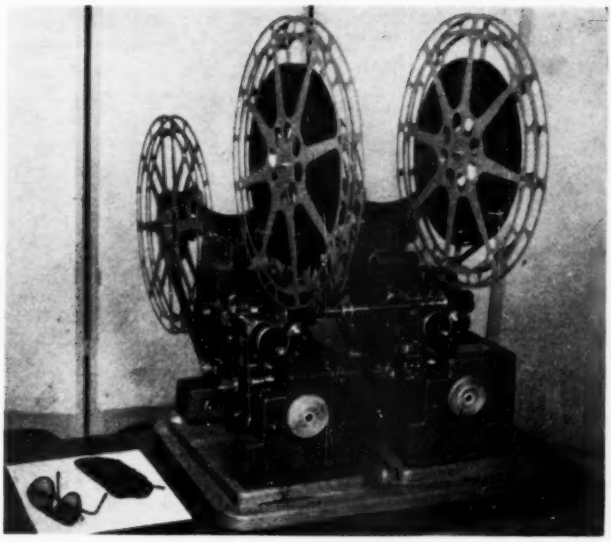


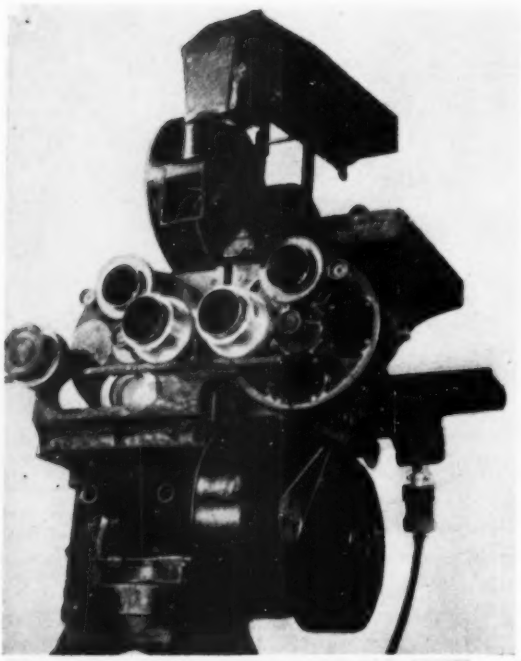
Fig. 22. Two 16mm projectors interlocked for stereoscopic projection.

appreciated. The enthusiastic public reception given some earlier stereo movies, and the dollar profits from these movies are a matter of record. Newer, better stereo techniques are now available, and the reason for introducing them was never more pressing.

The Anaglyph

One of the early and noteworthy theatrical exhibitions of stereoscopic motion pictures occurred in 1924, when J. F. Leventhal produced a few "shorts" utilizing the anaglyph process. There followed an 11-yr lull in the use of stereoscopic films. Then, in 1935, Loucks & Norling Studios and Mr. Leventhal jointly produced a series of short films again employing the anaglyph principle, this time in talking picture form. These films, which were called *Audioscopiks*, were released by Loews, Inc., and proved to be some of the most successful short subjects ever issued, winning not only domestic acceptance, but an unprecedented play in the foreign field, notably in France, Spain and Great Britain. That their success should have indicated further pursuit of the anaglyph process seems logical. But the producers had, from the beginning, realized the inherent limitations of the anaglyph process and concluded that films exhibited by that process would only be adequate as novelties and would never be tolerated for full-length feature releases. This conclusion was arrived at by a recognition of the visual "insult" resulting from the projection of one color to one eye and its complementary to the other. This sort of delivery of images, one color to one eye, another to its mate, produces "retinal rivalry" and brings on physiological disturbances that may induce nausea in some observers if they look at the anaglyph movie longer than a few minutes.

Since this process — the anaglyph — has played an important role in the advance of the stereoscopic art, it would be well to describe it here briefly. Its invention is credited to Ducos du Hauron, who applied it in 1895, although there



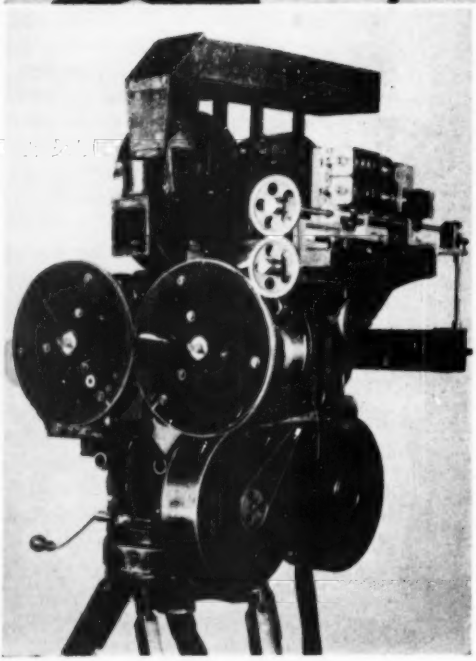


Fig. 23. Above, Bell & Howell 35mm camera interlocked for stereoscopic photography. Simultaneous focusing of the lenses is effected by rack and gears. Below, Bell & Howell 35mm interlocked cameras provided with three-color filter wheels for making stereoscopic color-separation negatives by the successive-exposure method. Used only for "stop-motion" work.

is some evidence that its possibilities had been explored many years before that.

In one form, the anaglyph images are on two separate films. One member of the stereoscopic pair is projected through a filter of one color, the other through a filter having a color complementary to that of the first. In another form, the one that was used for *Audioscopiks*, the anaglyph images are printed in complementary colors directly on film and projected in a standard projector without filters.

The projected images are viewed with spectacles having windows of the same colors as the colors on the screen. Red-orange for the right-eye filter and blue-green for the left are often used. The right-eye red-orange filter in the viewing spectacle renders the blue-green right-eye image in monochrome and the left-eye blue-green filter renders the red-orange left-eye image also in monochrome. Since dyes and pigments hardly ever are capable of transmitting only the color they are supposed to transmit, there is rarely a complete "cutting" of one color; some of it always comes through so that part of the blue-green image which is supposed to be blocked by the blue-green spectacle filter leaks through, producing a "ghost" image. So, in reality, one eye sees a part of the image intended for the other, the "part," of course, being defined as a very dim, but still discernible remnant of the whole "other-eye" image.

Good picture quality has never characterized the anaglyph. This and other shortcomings make it eligible for discard as a practical system for motion picture features.

Since the introduction of Polaroid light-polarizing filters, it is possible and practical to substitute these for the red and green filters of the original anaglyph process. Strictly speaking, the polarized light method may be defined as another form of the anaglyph. Actually, Polaroid Stereoscopy would be a good name for it, since Dr. Edwin H. Land, head of Polaroid Corp., invented the first practical and efficient synthetic polarizer which hastened the increasingly widespread use of the present satisfactory methods of stereoscopic projection.

Stereoscopic Motion Pictures at the New York World's Fair

The first large-scale public exhibition of a 35mm stereoscopic motion picture with excellent picture quality took place in 1939 at the New York World's Fair. That year a black-and-white film was shown. The following year a similar subject was exhibited in Technicolor. More than five million people saw these films,* and they're still talking about them. Some of the production and exhibition problems posed by these pictures are interesting to consider.

The camera assembly for the black-and-white picture consisted of two Bell & Howell professional 35mm cameras mounted so that one was "upside down" in relation to the other (Fig. 23). This was done so that the lenses could be brought close together. Even with this arrangement, the interaxial was not ideal. It was fixed at $3\frac{1}{4}$ in. although calculations showed that some scenes actually required as close as $1\frac{1}{2}$-in. interaxials. But no such camera was available then, nor was there time to have one built. However, a complete set of matched lenses of different focal lengths effected a quite satisfactory compromise with the ideal.

The greater part of the picture was a sort of fantasy, showing the parts comprising a Plymouth car dancing around and assembling themselves. Their movements were in synchronism with music and required the use of "stop motion" photography; that is, "one frame-at-a-time" shooting. But a substantial part of the film contained "live action" shots taken in the foundry and shops and along the assembly line. The narrator for the film was Major Bowes of

* Produced by the author.

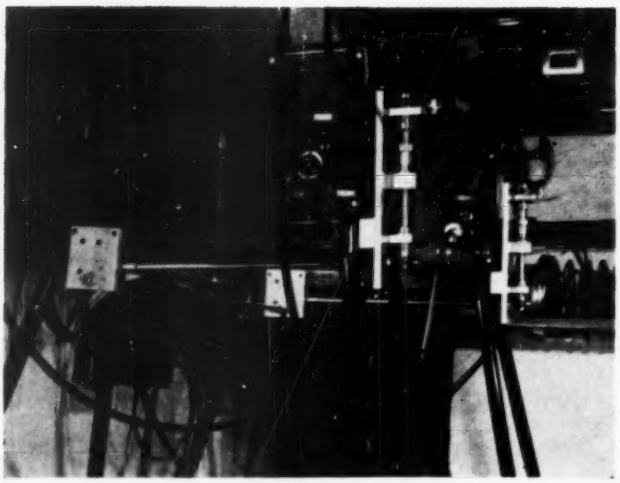
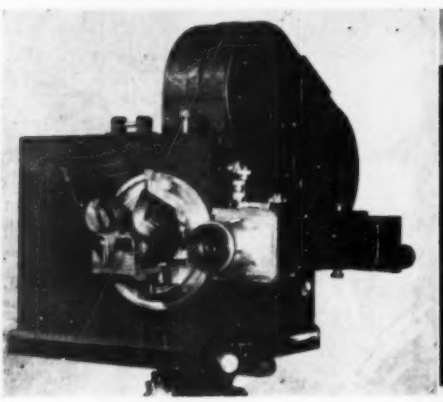
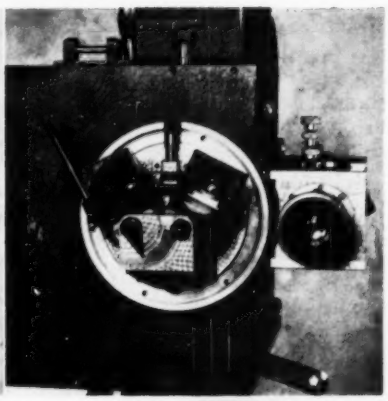


Fig. 24. Mechanical interlock of two 35mm projectors.





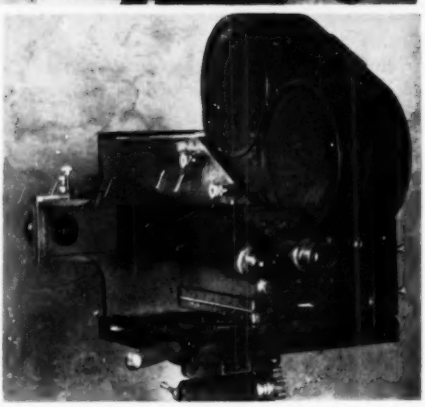


Fig. 25. Above left, the Loucks and Norling Studios' 35mm stereoscopic motion picture camera. Camera is in shooting position. Above right, front of the 35mm stereoscopic camera showing the variable interaxial system which has a range from $1\frac{1}{2}$ in. to 4 in. Right, the 35mm stereoscopic camera racked over for lining up the scene and focusing. The binocular viewfinder has interocular adjustment.

Amateur Hour fame. He appeared in "live action" in one sequence in which he spoke. This was the first "live action – live dialogue" shot ever made in a stereoscopic presentation. It created some difficult problems since the cameras would not fit into any available studio "blimps." However, the sequence was shot without any parasite camera noises being recorded, thanks to the intelligent help rendered by Walter Hicks, then of the New York Fox-Movietone Studios.

Since the Chrysler film was shot in a two-camera setup, and no special photographic and projection facilities for single-film handling were available, it was necessary to project with two projectors (Fig. 24). A rather complex selsyn motor drive was used for interlock, although a much simpler synchronization could have been attained by a straightforward mechanical linkage, such as was used for the Pennsylvania Railroad stereoscopic movie display at the Golden Gate International Exposition in San Francisco in 1940.

The dual projector system used at the New York and San Francisco Fairs is substantially the same as that recently on exhibition at the Festival of Britain. According to press reports, it is also the same system which has recently been demonstrated by the Natural Vision Corp. of Hollywood.

A Technicolor film, using the stop-motion technique as well as live action shots on monopack was our next stereo production. For the stop-motion sequences, a unique filter attachment was arranged in front of the camera lenses. The filters were mounted on wheels which rotated together. Color balance was attained by making sectors having angular dimensions calculated to pass the quantity of light required for each color and as demanded by the sensitivity of the film. The "A" (red) filter passed light to which the film was more sensitive than that passed by the "B" (green) and "C5" (blue) filters. Consequently, the red filter had the narrowest opening of all and the "C5," to whose transmission the film was least sensitive, had the widest opening. The exposures were made by the alternate frame method of color separation. Three frames, one the red record, one the green, and one the blue, were made instead of one frame as in ordinary photography. This procedure is followed in the photography of animated cartoons.

These separation negatives were used by Technicolor to make the printing matrices from which the dye imbibition prints were produced.

It has always been the author's opinion that the stereoscopic camera for professional use should be built to take the images on two separate films. This is to afford the greatest flexibility in the studio and to permit the use of short focus lenses and to facilitate the making of optical effects in the duplicating processes. One such camera was built (Fig. 25). It contains the features deemed essential to a versatile camera. The most important are a variable interaxial and a convergence control, but important too is a binocular finder showing in miniature a three-dimensional view of the scene to be photographed. Visual inspection during focusing seems superior for stereoscopic work and focusing is easier when the view is seen in three dimensions. The binocular viewfinder has an additional advantage: it enables the cameraman to compose the scene stereoscopically using the interaxial and convergence controls, manipulating them until he gets the best possible arrangement. He can increase the interaxial if he wants to increase the apparent depth of the scene. He can reduce it if nearby objects demand it.

Dual Images on One Film

Systems for stereoscopic films using dual images side by side or one above the other have also been proposed. One of the problems in the two-image arrangement, whether in tandem or side by side, is the loss of light, because the light-covering circle covers a large area around the area occupied by the two images.

The ordinary circular light spot from the projector arc spills light all around the images. This condition can be improved upon by a light condensing system having a cylindrical lens element. Then the light spot becomes oval instead of round (Fig. 26).

The Newcomer Anamorphoser

Another method is to introduce an optical device on the camera to compress the images in one direction, and a similar device on the projector to expand them back to normal proportions. Such an optical device is called an "anamorphoser" (Fig. 27). Several types have been constructed, but it remained for Dr. H. Sidney Newcomer to design one that does not introduce serious aberrations and have other optical handicaps. The Newcomer Anamorphoser is capable of effecting a compression of the image to almost $\frac{2}{3}$ and an expansion of almost $1\frac{1}{2}$ times.

The Beam Splitter

Among the methods suggested for the employment of a single film to carry the two images is the "beam splitter" in one form or another (Fig. 28). The device has two pairs of mirrors (or prisms) placed in front of the lens and arranged so that the pair on the left will cause the left-eye image to be selected for projection to the screen and the right-hand pair will do the same for the right-eye image. It is a simple device and easy to use.

The beam splitter is a device that does exactly what its name implies; it splits the light beam into two parts. Hence, the intensity of each part cannot be greater than half of the whole beam. But in addition to light loss, it has another drawback. The pictures overlap considerably, making it impossible to mask them to a stereoscopic window. The window must be artificially produced by a black border on the screen to absorb spill-over light. Another shortcoming: The camera lens works at something less than half the f/stop setting shown on the lens. This means more than twice the amount of light required for conventional photography. When it comes to shooting interiors, this added light requirement proves to be an economic disadvantage of the beam splitter method. There is a corresponding light loss in projection, and here the loss is even more significant. Take the loss inherent in the beam splitter, add that to the loss in polarization and you find that you're getting about one-twelfth the light that you had when you projected the full frame in the conventional way. Another disadvantage of the ordinary beam splitter is the picture proportions it gives — a narrow and tall picture, certainly inappropriate for stereoscopic representation which is so well suited for panoramic views.

Another proposed device has dual lenses producing pictures side by side. There is no light loss in the camera, since two lenses are used and the window for each picture is quite sharp. However, there is considerable loss in projection if the attachment is used on a projector not provided with a special condenser system. If the standard proportions are retained, each image is less than one-fourth the area of the full frame.

Another method which has been proposed for simultaneous projection, is the arrangement of images with one member above the other. Special projectors would be required.

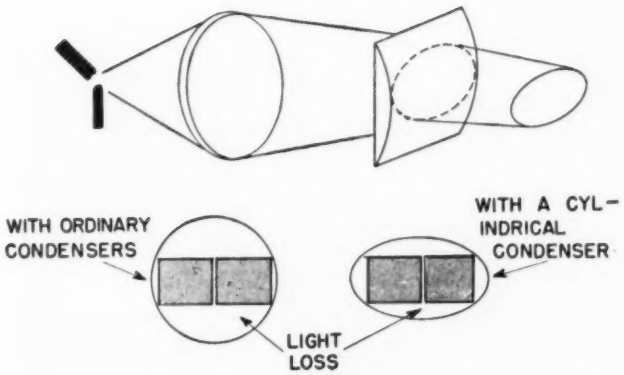


Fig. 26. A light-condensing system that improves the light distribution to dual images.

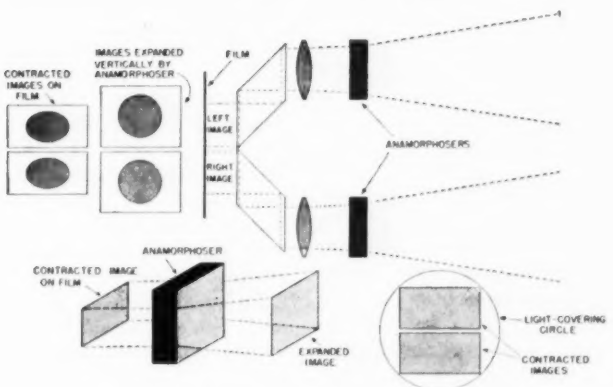


Fig. 27. Diagram of the "Anamorphoser" principle applied to motion picture stereoscopy.

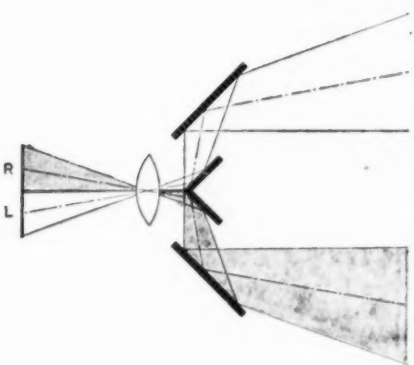


Fig. 28. Diagram of one arrangement of the "beam splitter."

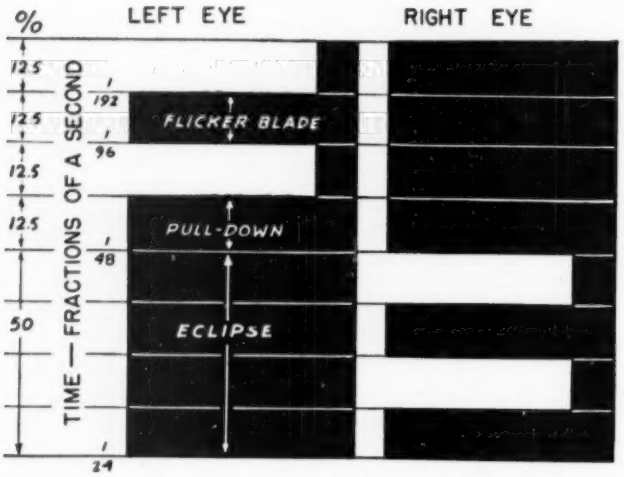


Fig. 29. The light and dark periods in "eclipse" stereoscopic projection.

Sequential-Frame Projection — "Eclipse" System

From time to time, the alternate projection of the members of a stereo pair has also been proposed. In this system, the right-eye image, for instance, is projected first, then the shutter interrupts the light beam while the film moves down to position the left-eye image. Thus there are periods of flicker that occur at different times for each eye. If we break this sequence of events down, we find that the first light period has a value of 12.5% of the complete picture cycle. The flicker blade on the projector shutter (considering a two-bladed shutter) gives a dark period lasting 12.5% to be followed by a light period of the same, then a long dark period consuming 62.5% for pull-down and eclipse to permit the other eye to see its image (Fig. 29). If standard sound-film speed of 24 frames/sec is used, the resulting flicker is very annoying. Stepping up the projection to 48 frames/sec increases flicker frequency twice, but it still is noticeable. There is a physiological effect that is likely to become disagreeably apparent — usually headache or nausea — after a few minutes of viewing pictures projected in this way. A complete period of darkness for one eye, while light reaches the other, will probably always result in visual fatigue, if not in nausea, no matter how high, within workable limits, the flicker frequency is brought.

Flicker of low frequency calls for traction on the control muscles of the irises when bright light enters one or both eyes. The rapid occurrence of the transmission of stimuli, first from one eye, then from the other, and the motor messages from the brain to the muscles, delivered in rapid sequence, probably accounts, in part, for the visual discomfort experienced by most people when viewing "eclipse" stereo movies.

Perception of flicker depends upon the intensity of the interrupted light, as well as the flicker frequency. The more intense the light, the higher the frequency must go before flicker fusion is attained. Also, the larger the angular field over which flicker is distributed, the greater the consciousness of flicker. Hence the dimmer the picture and the smaller it is, the lower becomes the flicker fusion frequency.

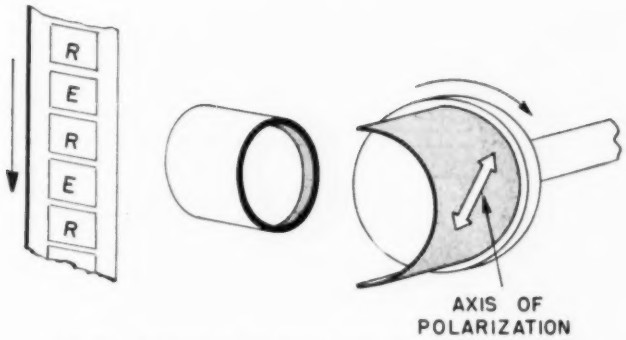


Fig. 30. Diagram of the "rotating polarizer" method of alternate frame stereoscopic projection.

There are two ways to project and view eclipse stereograms. One is by using rotating or vibrating shutter devices held up in front of the eyes. These are synchronized electrically with the projector. The other method is to employ a rotating polarizer in front of the projector lens and polarizing spectacles for the viewer (Fig. 30). In one position the polarizer delivers light through the left spectacle filter, in the other through the right filter.

Alternate-frame, or eclipse, projection should have at least twice the number of frames required for conventional films. That means doubling the length and providing for faster projection speed. If the alternate frames are photographed alternately, there is a very objectionable fringing in pictures of moving objects. This is a cause of eyestrain, especially in a picture where the action seen by one eye is in quite a different stage of progress than the action seen by the other. Difficulty in fusion invariably results. This combination of disturbing effects, caused by flickers out of phase between the eyes and by fusion trouble, limits the appreciation of the eclipse method.

Complete visual comfort can be attained in stereo movies only if the two images are projected simultaneously, if they are rock-steady, if they are of equal brightness, if they are of equal contrast, if they are properly aligned vertically and horizontally, if far distant points are not separated too far in one image from that of the other, and if they are of exactly the same size.

Improved Single-Film Methods

Several inventions by the author eliminate the drawback of the single-film dual-image arrangement, namely the unequal distribution of light. These methods employ novel optical systems which are accessory attachments to standard projector heads.

If one member of a stereogram has even a slightly different brightness, some eyestrain will result. If the difference is large, the resulting eyestrain will be great. This is because the action of the eyes' iris diaphragms is entirely automatic and not by voluntary control. If strong light falls on one eye, both pupils will contract and the eye seeing the darker image will have its pupil closed down more than it should be properly to see the image. In accommodation too, both eyes act together and it is impossible for one independently to accommodate to a different extent from the other.

The improved single-film methods satisfy one of the basic requirements for good stereograms, easy to look at, in that both members of the pair are of the same brightness. The illustration

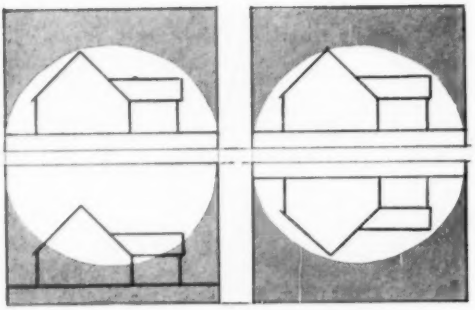


Fig. 31. Illustrating the distribution of light over a pair of images. Left, as in an arrangement wherein both images have the same position. Right, as in an arrangement wherein one image is "flipped over" in relation to the other.

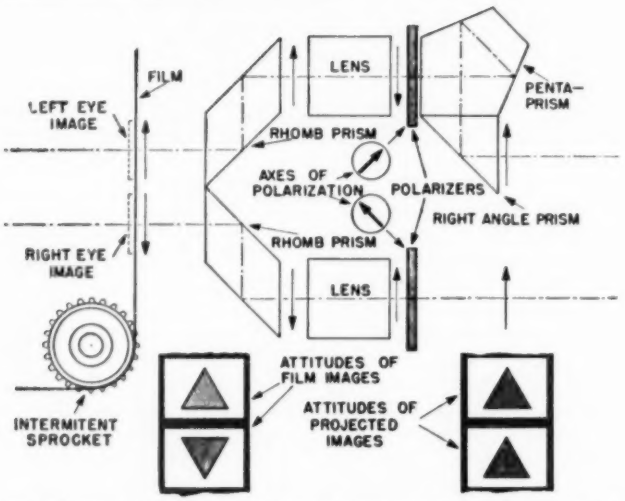


Fig. 32. Diagram of an improved optical system for simultaneous projection of the two images comprising the stereoscopic pair.

shows a pair of pictures having image attitudes in a conventional arrangement. The diagram on the right shows an improved arrangement. It affords the best possible distribution of the light from the projector arc (Fig. 31).

The illuminating spot from the arc is considerably more intense in its center than in its outer regions. With images having the attitudes shown in the left-side diagram, more light falls at the top of one picture than at the top of the other, resulting in a different level of illumination in an area of one than in the corresponding area of the other. The arrangement shown on the right provides equal illumination in corresponding areas because all portions of the light spot fall upon the same corresponding areas in each member. This meets the requirement that there be equal brightness for each image in order to attain complete visual comfort. It may seem surprising that the intensity difference between center and edges of the light circle is significant. Actually, in practice, projection engineers are quite happy if there is only a 40% loss — 60% as much light at the edges as in the center. In many theater installations, the fall-off is as much as 50%.

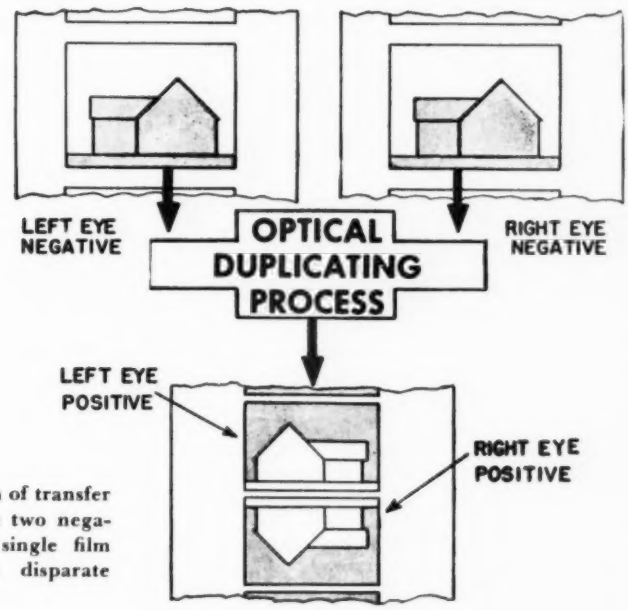


Fig. 33. Diagram of transfer of images from the two negative films to the single film carrying the two disparate images.

The projection end of this system, using standard projector heads, has two optical trains containing prisms as well as lenses (Fig. 32). These components are arranged so that the light beam enters and exits normal to the prism surfaces and there is no displacement or distortion such as would take place with wedge prisms. Alignment of the images on the screen is effected by a micrometer control to shift the lenses. In the lower optical train, transmitting the right-eye image (the one having the conventional attitude), the image passes through in the conventional manner, reversing to "heads up" in the projection lens. In the upper optical train, transmitting the left-eye image (the one having the "flipped over" attitude), the image is brought to conventional attitude in a pentaprism and right-angle prism forward of the lens. The polarizers are placed in front of the lenses away from the intense heat.

Prints for this system of projection are not made directly from the original negatives. Duplicate negatives produced in an optical duplicating process are used instead (Fig. 33).

Another improved single-film method has the images turned on their sides (Fig. 34). This arrangement provides for the use of the full standard aperture in case the pair of images is to occupy only one standard frame. A series of prism elements between the film and the lens turns these images 90°. The inverted image is "flipped over" in the pentaprism and right-angle prism in front of the lens. Otherwise, the practical advantages of this variation are comparable to those of the method which is discussed in the preceding few paragraphs.

Another method, devised by the author for attaining equal illumination for both members of the stereoscopic pair is also illustrated (Fig. 35). Here, there are two mirrors arranged between the light source and the film. The lower mirror is a transmission-reflection type, with a reflective coating that will reflect half

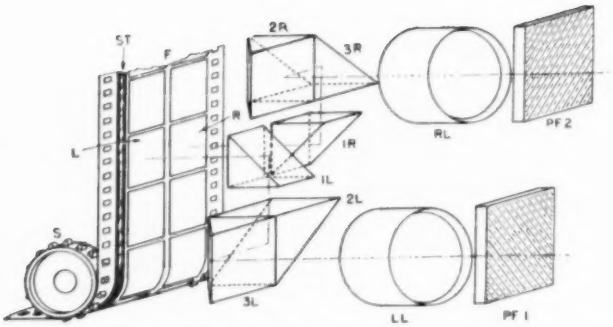


Fig. 34. Improved single-film method with the images turned on their sides.

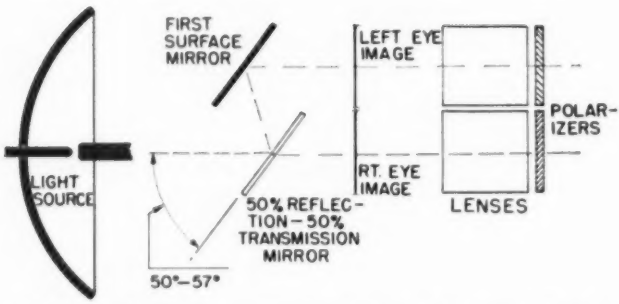


Fig. 35. Illustrating an arrangement that provides equal illumination for both images by using a partially transmitting mirror.

the light to the upper mirror, one-half the light passing through to one member of the pair. The upper mirror reflects one-half the original light beam to the other member. Again, two projection lenses are used, as in the other systems with the polarizers in front of them.

In this system the images *do not have to be inverted* in relation to each other, since the illuminating circle falls upon the same corresponding area in each. The light-circle can be reduced in size to fit the area occupied by one frame, adding efficiency. Added efficiency also results from the reduction in the number of glass-to-air surfaces. Additionally, there is less possibility for dirt or "fogging" on the optical elements. In contradistinction to the other methods, which require no lamphouse changes, this method does require a few changes in the lamphouse to accommodate the two mirrors.

A dual-image single-film does not add significantly to print costs, to the costs of studio production, to shipping and handling costs between exchange and theater, nor does it require dual projectors and added labor costs for projection. This single-projection method does not introduce the unwanted possibility of images out of synchronism with each other, a hazard that exists in dual projection. It assures precise registration, one image with the other. Alignment is no problem, since both images are framed together by the same frame-setting lever. There can be no jiggling or jittering between the images such as is present in any dual system no matter how well made the projector mechanisms.

The Friese-Greene Process

The first stereoscopic motion picture was made by William Friese-Greene who patented his process in 1893. He used two negative films, one behind each lens. The positive images were projected side by side on a screen and viewed through a cumbersome stereoscope permitting each eye to see only the picture intended for it. The complexity of this system barred it from any commercial application.

The Grid System

The grid system has been frequently proposed and a large number of variations on the basic method have been suggested during the past 40 years (Fig. 36).

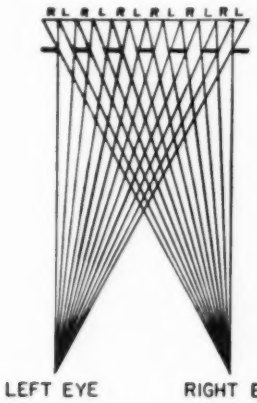


Fig. 36. Diagram of the fundamental "grid system" of stereoscopy.

Basically, the grid system employs a screen containing a large number of vertically placed parallel opaque bars forming a grating having open or transparent spaces between them. This grid is placed some distance in front of the projection screen, the grating in the grid being designed so that the right eye sees only that portion of the screen on which the picture record for the right eye appears, the bars in the grating hiding the left-eye image from the right eye. It does the same thing for the other eye.

The chief problem in using the grid system is that the observer's viewing distance, angle of view, and of eye placement in relation to the grid are of a fixed interlocking relationship. Disturb one of the three and proper viewing fails. A slight shift to the right or left results in the breakdown of "correct individual seeing" for each eye, and a double image becomes apparent, or else a pseudoscopic effect results. Improvements have been made on the basic grid system, but serious shortcomings still remain as an intrinsic part thereof. This particularly applies to the loss of light. While a light loss is common to all stereo projection systems, it is particularly severe in this one, due to the fact that the opaque areas in the grating have to be (in most cases) about three times that of the open areas in order to keep the images from overlapping.

Another matter that must be given consideration is the appearance of the grating to the observer. The dark bars and light spaces should be small enough to be virtually invisible as a banded pattern. To make the grating lines invisible, the spacing of the elements should be no larger than about $\frac{1}{3500}$ of the viewing distance.

We shall call the grating space G_s; then

$$G_s = \frac{D_v}{3500} \text{(or more)}$$

where D_v is the viewing distance.

Thus, if $D_v = 60$ in., $G_s = 0.0175$ in., approx.; and if $D_v = 120$ in., $G_s = 0.035$ in., etc.

The distance, d_g, of any selected grating in front of the screen depends on the relationship of the distance D_v to d_g, or by the relationship of I to D_v.

With the usual grid system, the picture through the grating is viewed by converging the eyes at or near the grating,

forming an angle. In order for the grating effectively to select the images properly for the eyes, the disparate members of the stereoscopic pair must be projected through the grating at the same angle.

The *New York Times*, early in 1944, reported that Simyon Ivanov, a Soviet poster artist, had invented a screen made up of tiny squares of thousands of strands of fine wire which produced 3-D effects without the use of eyeglasses. James Aldridge, writing on the same subject for the North American Newspaper Alliance, reported that the images reproduced through the screen were "coarse and blurred."

The article goes on to say that the original Ivanov grid system had been improved and developed in the Sgvintorgkino Studio to the point where it promised to become practicable. To quote from the article:

"The glass screen is engraved with more than 2,000 converging lines, and it is in these markings that the secret of the new screen lies. In photographing third-dimensional movies, the only alteration required on standard cameras is the addition of two or more mirrors fitted near the lenses to reflect the images onto the film."

Obviously, this appears to describe Ivanov's photographic process as being an application of the beam-splitter principle. The article goes on to say:

"In showing the film, it is projected onto 'two or more mirrors,' instead of directly onto the screen, which reflects the shadows onto the glass screen. In turn, the lines on the screen unscramble the images, resulting in a clearer image than has hitherto been obtained in third-dimensional film experiments."

Then, in October 1945, the *Wall Street Journal* reported further on the Ivanov development:

"Moscow (AP) — The Soviet film industry is preparing a surprise for the world's movie fans — a special production of *Robinson Crusoe* to be exhibited on a new stereoscopic screen designed to give rounded, three-dimensional images.

"Semeon Pavlovich Ivanov, the inventor, said that the screen creates an illusion so perfect that people unconsciously dodge when pictures of birds or airplanes are shown.

"Ivanov said he believed the screen surpasses anything Hollywood had done to achieve realism in the exhibition of motion pictures."

On April 29, 1948, the *New York Herald-Tribune* published the following:

"Moscow, April 28 (AP) — The Communist newspaper 'Pravda' disclosed today that Semyon P. Ivanov, described as the inventor of three-dimensional motion pictures, had been removed from the job of scientific chief of the special studio in which he perfected the invention.

"The newspaper (Pravda) said that I. Bolshakov, Motion Picture Minister, did not take Mr. Ivanov's work seriously, tried to picture him as a faker and publicity seeker and finally pulled him off with the excuse that he was freeing him from his administrative duties."

Pravda went on to state:

"That's how the cinema industry freed itself of the worrisome individual whose name will go down in the history of the Soviet and world cinema."

Truly, workers on the grid method of stereoscopy have a bad time when someone eventually discovers that the images don't appear satisfactory throughout an auditorium.

Parallax Stereograms

Parallax stereograms are of two principal kinds, one using a grating, or "grid," as the selecting screen placed in front of the images, and the other using a selective screen consisting of small cylindrical lens elements, lenticules, side by side, and running vertically.

The "grid" system was introduced by Berthier in 1896 and was the first form of stereoscopic viewing of still pictures that did not require accessories. The grid consisted of vertical bars with spaces

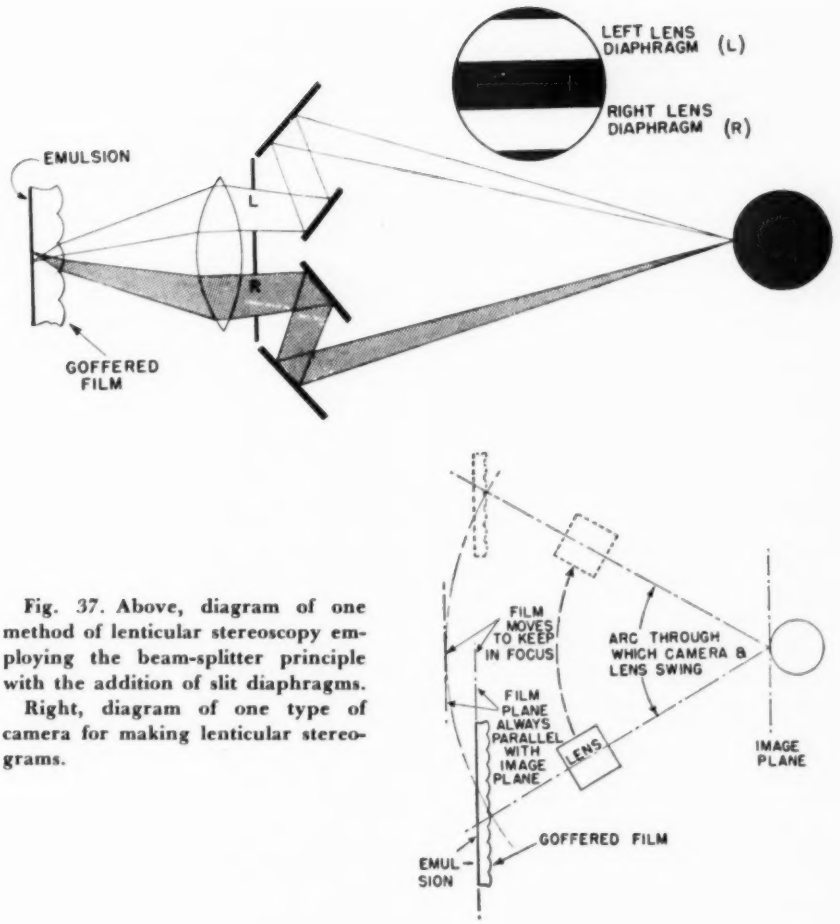


Fig. 37. Above, diagram of one method of lenticular stereoscopy employing the beam-splitter principle with the addition of slit diaphragms. Right, diagram of one type of camera for making lenticular stereograms.

in between. The grid was usually made on a high-contrast photographic plate. The picture was a composite which had the two images broken up into bands, the image bands for one eye being interlaced between the image bands for the other. When the grid was spaced at the prescribed distance in front of the composite and viewed from the correct distance, the observer was able to see a binocular view.

The "lenticular" system used a selective screen sometimes registered in front of the images; sometimes directly bonded to the composite photograph. The lenticules do not cut down the reflected light as do the bars in the grid system. In one system, the composite picture is made in a single-lens camera which swings through an arc during exposure. The center of the arc is in the plane of the subject (Fig. 37).

Lenticular systems are credited to several inventors; among them F. E. Ives and his son, Dr. H. E. Ives. Dr. Ives called his the "Parallax Panoram-

agram." Improvements have been made and further developments carried out by the Americans, Vanbenschoeten and Winnek, and the Frenchman Bonnet.

The Zafiropulo Process

Another invention employing the lenticular principle is that of Jean Zafiropulo, who set out to apply it to the motion picture in particular. The process requires extremely accurate alignment of all elements in photography and projection.

The Zafiropulo process involves the use of a film containing embossed spherical lens elements in its base. Prints must have their lens elements exactly aligned with those in the negative. The lens elements must register with the greatest exactitude in relation to the sprocket holes in the film. Sprocket teeth, engaging the sprocket holes, serve as the basic registration points for picture steadiness. Film shrinkage, which is over 0.25% in the lowest-shrink film base, will have to be overcome to prevent lens-element misalignment with relation to the sprocket teeth, and in turn to prevent misalignment of the film lens-elements and the screen lens-elements.

The Zafiropulo process requires only one lens in photography, but it must be of large diameter, from $2\frac{1}{2}$ in. to 3 in. and such a lens must be of long focus, over 6 in. in an $f/2.5$ lens. This is about 153 mm compared with 40-mm and 50-mm lenses, which are the most frequently used in film studios. This long-focus lens requires more studio space than is needed in conventional filming.

Several other methods have been proposed for the lenticulated (goffered) film process of movie stereoscopy. One is, in essence, an application of the "beam splitter" principle, differing from it in that it produces a series of bands for each image (Fig. 37). One band, for part of the left-eye image, is formed through each lenticule, and another band is formed adjacent to it for the corresponding part of the right-eye image, through the same lenticule. The lens must be operated at its widest aperture.

Lippman's "Integral System" of Stereoscopy

The process of "integral" photography discovered by Lippman in 1908 utilized a screen composed of an almost infinite number of small "lens elements" in the form of pin-holes. It affords what most who have seen it consider the ultimate in stereoscopic viewing. It differs from any other system of stereoscopy in that it provides a much larger number of images in the plane of the photograph and "reduces the number of viewing instruments to zero." But Lippman's integral photographs can be made only as transparencies, and they cannot be projected, nor can they be reproduced to supply copies that have the qualities existing in the original.

These integrated stereograms are made through a screen having a great number of pin-holes, each acting as a camera lens. No camera is used; the pin-holes serving as lenses. The screen can be a photographic image in a contrasty emulsion on the front side of a glass plate with the photographic image produced through it on an emulsion on the back. The holes must be quite small; their size being established by the rules applying to pin-hole photography. There must be a great number of holes for every square inch, and the plates should be quite large, 8×10 in. or more.

Exposure is made through the pin-holes, and since the effective aperture of each pin-hole is extremely small, long time exposures are essential. They cannot be satisfactorily reproduced; hence copies are not obtainable, and the negative image has to be rendered into a positive by reversal. Viewing should be with a mirror placed so that the proper left-right attitudes of the images can be obtained.

The nature of the process excludes it from practical usefulness, particularly

for motion pictures, but it is an interesting thing with which to play, and can be experimented upon by anyone having the required facilities.

Single-Lens Camera for Motion Picture Stereoscopy

If two strip stereo films are used, such things as titles can be made by exposing one image, for the required footage, then shifting the camera to expose the other, as is done in making "slide-board" stills referred to earlier in this article.

A variation of the principle can be applied to obtain stereoscopic motion pictures, especially aerial shots. The author has made such films using only *one* camera, and making only *one* negative. Two prints were made from these single negatives and projected in interlock on two machines. However, the prints were projected with one print having its frames displaced in relation to those of the other. The number of frames displaced is governed by the plane's elevation above the ground and above the nearest object, in scenes looking straight down. Frame displacement is also governed by the ground speed of the plane. A plane flying at 100 mph will cover 144 fps, which means that a distance of 6 ft is covered in every second for a film speed of 24 frames/sec. A full reel was made during flights over New York City, the camera pointing straight down. The plane was flown at 2500 ft, and slow-motion photography of 96 frames/sec was used.

A film speed of 96 frames/sec with a plane speed of 100 mph gives $1\frac{1}{2}$ feet of advance along the course as registered by every frame. Using the equation, $\frac{D \times d}{D - d} \div 50$, established the base of the interaxial that would result in the most startling visual effect with the least eyestrain. The farthest plane, D, the ground; the nearest plane, d, the top of the Empire State building; and the divisor, 50, indicated an interaxial base of 40 ft and this was achieved synthetically by a displacement of one film with the other of 30 frames. Actually, a displacement of 15 frames was finally selected to give the most satisfactory results.

Some stereo shots were made up in this way from stock footage taken from a plane flying over the Andes. The plane was flying about 180 mph and the exposures were made at normal camera speed. The camera pointed horizontally toward the distant mountains.

The most startling of these shots was one that included "The Christ of the Andes." This heroic statue was in the middle distance and stood out in vivid relief against the mountains beyond.

There is one thing that creates quite a problem: any unsteadiness in the airplane's flight. This comes out in the projection as a constantly changing vertical and horizontal, and sometimes rotational displacement between the images. Such displacements existed in the films we made and had to be eliminated by optical duping methods involving a complexity of steps. But it was an interesting experiment and worth the trouble.

The Vectograph

Vectograph is the name applied to a clear plastic sheet on which an image may be rendered in terms of varying degrees of polarization, and viewed through a polarizing filter. The vectograph can accommodate an image on both its sides, and each image can be made to have its axis of polarization at right angles to that of the other. A stereo vectograph has the images of a stereo pair printed respectively on top and bottom of a vectograph sheet, and is viewed through polarizing spectacles with its respective windows having polarizing axes corresponding to those of the vectograph images. In slide form, the 3-D vectograph can be shown in a standard monocular projector without filters. As in other systems using polarized light,

silver non-depolarizing screens and polarizing viewing spectacles are required.

During World War II the 3-D vectograph was used by the armed services for aerial reconnaissance and for training personnel in various skills. Other uses for this novel, paper-thin stereo picture will doubtless be found. Its picture quality is excellent and its ease of handling and processing are distinct advantages for any photographic process.

3-D Pictures and Television

Inevitably today, any new method of visual presentation, both still and motion, can be telecast. As a matter of fact, an experimental stereo-television system has been at work in the Argonne National Laboratories. It permits an operator to keep a precise watch over the "hot" materials he is handling by remote control. Equipped with a pair of viewing spectacles and with eyes glued to a pair of television screen images which are transmitted by a binocular television camera, the operator does get a 3-D impression. But the problems involved in presenting satisfactory 3-D television to the public may be so very great that, by comparison, the problems of introducing *color* television have been small indeed. It is anybody's guess when stereo television will enjoy a widespread audience; if the history of stereo movies can provide a clue, the time is many years away.

Nonstereo System

A system which has recently been described as producing a 3-D effect is the Cinerama development of Fred Waller. This method, requiring a multiplicity of cameras and projectors, presents a dramatic panoramic view of the scene photographed. But it is not 3-D at all, since it does not present a mutually exclusive image to each eye, the basic requirement of any 3-D system.

GENERAL DATA

For successful stereoscopic projection, it is important to know the size to which the picture is to be projected, for upon this knowledge depends comfortable viewing or maximum effectiveness, or both. Distortion of the subject for the spectator depends on his viewing distance and the angle at which he views the picture, but as in conventional movies, distortion due to the spectator's viewpoint is not serious unless he is very far off screen center or extremely close to or very far away from the screen.

Stereoscopic Terms

There are certain terms used in stereoscopy. These are:

The Stereoscopic Window: The "frame" behind which the scene apparently exists in space. In some cases, elements of the scene may extend in front of the window. These are special effects, and do not belong in a discussion of basic principles. The symbol is Sw.

Interocular (I_o): The distance apart of the human eyes. We may select 2.5 in. as the interocular.

Interaxial (I): The distance apart, or horizontal spacing of the stereo camera lenses, more truly the spacing apart of the central axes of the picture area.

Major Distance (D): The distance from the lenses to the farthest object.

Minor Distance (d): The distance from the lenses to the closest object. This is often the plane at which the stereoscopic window is planned to exist. In most cases, the nearest object will be a slight distance in back of the nearest plane.

Width of Image (w): Refers to the width of that part of the negative which is to be used in the final prints. For standard 35mm theatrical film, this is 0.825 in.; for 16mm, 0.4 in.; for Stereo-Realist slides, 0.875 in.

Focal Distance (F): Refers to the dis-

tance from the principal node of the lens to the film, and does not refer to the equivalent focal length of the lens, although in most cases the stated focal length may be considered the focal distance. It is only for extreme close-ups that a differentiation must be made.

Parallax Index (P): This refers to the parallactic difference between disparate members of the stereoscopic pair when projected. The parallactic difference is determined by the following factors:

1. The distance to the nearest plane in the subject.
2. The distance to the farthest plane in the subject.
3. The ratio between image width and focal distance of the lenses used.
4. The interaxial used.

Parallax index can be expressed by the equation

$$I = \frac{W}{PF} \times \frac{Dd}{D - d}$$

This equation was derived from the accompanying diagram, which represents the geometry of the system of taking stereoscopic photographs (Fig. 38). Calculations are simplified if we consider one of the lenses collinear with the far and near points.

Points D and E represent the positions of the two lenses. The distance DE is the interaxial "I." Distance DA or EA is the lens to film distance, and its symbol is "F." F and G are points on the nearest and farthest planes in the subject. DF is "d" and DG is "D." BC is the horizontal shift on the image plane created by points F and G, and this distance has the symbol "S."

It will be seen that, if the nearest point is superposed on the screen, the farthest point will be separated by an amount determined by the interaxial used in taking the picture. The maximum value of the distance of homologous points on the screen should not exceed $2\frac{1}{2}$ in. to avoid visual discomfort. To the observer, homologous points back of the stereoscopic window which

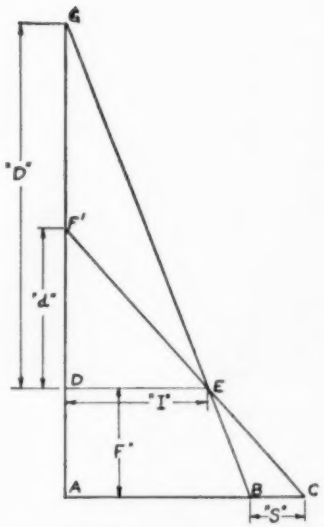


Fig. 38. The geometry of the stereoscopic process.

are $2\frac{1}{2}$ in. apart should appear to be at virtual infinity. Some individuals can tolerate $3\frac{1}{2}$ to 4 in., but it is best not to use "super infinity" if it can be avoided. Homologous points that superpose on the screen will seem to lie in the plane of the stereoscopic window.

The minimum distance at which observers can look at a picture comfortably when it has a $2\frac{1}{2}$-in. maximum separation of points is about 6 ft. In general, the maximum horizontal displacement should not exceed $\frac{1}{30}$ of the viewing distance. This requirement exists because in viewing projected stereo pictures, the observer must "uncouple" the facilities of convergence and accommodation of the eyes.

In viewing, it is desirable that the parallax index be 24 or greater.

Parallax index P may be stated as

$$P = \frac{D_v}{I_n}$$

where D_v is the viewing distance, and I_n is 2.5 in.

Thus where $D_v = 60$ in., $P = 24$; where $D_v = 120$ in., $P = 48$, etc.

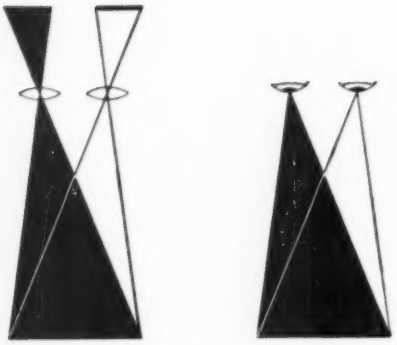


Fig. 39. The principle of lens angle and viewing angle.

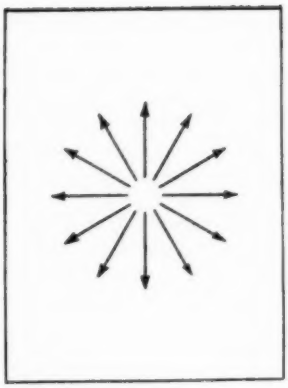


Fig. 40a. Representation of a cluster of light vibrations.

General Rules: 1. A general rule can be laid down for the photography and projection of stereoscopic views: *The projected view should have the same angular dimension for the viewer as the scene taken by the camera.* This is the ideal, but never attainable in practice except for just one person at the prescribed distance from the screen and viewing the screen along the projection axis (Fig. 39).

2. The apparent depth of the stereoscopic view should be the same as the real depth of the scene. To attain the right apparent depth, the correct interaxial must be employed. The required interaxial varies over a wide range and for projected views must be given much more serious consideration than for hand-held views. If we plan to project on an 18-ft wide screen, we must not use as wide an interaxial as we can use on a 6-ft screen, because if we do, and employ convergence to establish the stereoscopic windows, we are either going to have homologous points at infinity spread so far apart that the eyes have to diverge to accommodate for them, or we are going to have to adjust the projected stereoscopic window to a plane far in front of the screen.

It is not difficult to arrive at the correct interocular if we use the simple equation

$$\text{I (interaxial)} = \frac{\text{w e d}}{\text{sf}}$$

where w = width of the image on the film,
e = normal human interocular ($2\frac{1}{2}$ in.)
d = distance from the camera lens to a plane just in front of the nearest object (plane of convergence),
s = width of the projected picture,
f = focal length of the camera lenses.

The establishment of the stereoscopic window is not of great importance in hand-held views, but it must be employed in projection, and properly employed. If it is not, there will be the marginal disturbances that have been mentioned before, and they are hard to look at. There is nothing in natural vision to correspond to them, and since the ideal stereoscopic view is one that should afford *complete visual comfort*, the appropriate window frame should be calculated in every scene. If it is not, people may have trouble looking at your stereoscopic "masterpieces."

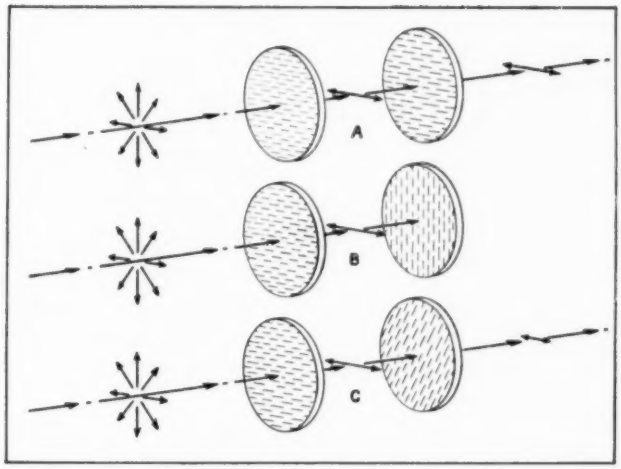


Fig. 40b. Light passing through two plane polarizers: A, with axes parallel; B, with axes at 90° to each other; C, with axes at less than 90°.

Very striking stunt shots can be made stereoscopically. For instance, objects can be made seemingly to float in space between screen and observer provided the object is well inside the margins of the picture areas. Objects should not be photographed so as to appear so near to the person observing the projected images that he will have trouble fusing them. Consideration must be given to the accommodation limits of the eyes; that is, for convergence accommodation limits.

Theoretical accommodation limits of the human eye in convergence are based on normal close reading distance of 15 in. (Note: This formula does not take into consideration what physiological effect, if any, is introduced when the accommodation muscles are used without correlative focusing.) The angle of convergence of the eyes (interpupilary distance of 2.625 is used) at a distance of $16\frac{1}{2}$ in. is slightly more than 9°. The displacement of the disparate images on the screen are given in inches and decimals of an inch.

Formula: Observer distance from screen less 15 in. multiplied by the tangent of half the angle subtended by the eyes gives the maximum separation on the screen at a given distance. To obtain the required separation of images on the film, divide the projection aperture width by the screen width and multiply by the separation of the projected images (tan 4° 30 ft × distance from the screen).

Observer distance from screen, ft	*Maximum separation on screen, in.*
4	2.60
6	4.48
8	6.37
10	8.26
12	10.15
16	13.93
20	17.71
24	21.48
30	27.15

An Analysis of Light Polarization

Since the phenomenon of light polarization is so closely related to the practice of stereoscopy, it is of benefit briefly to review it.

Let us imagine we are looking head-on

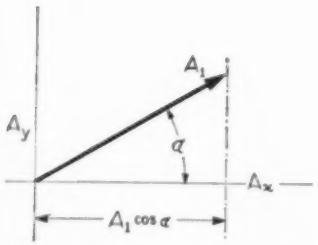


Fig. 41. Vector diagram of a vibration.

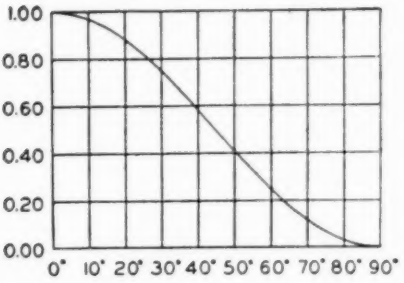


Fig. 42. Relative transmission of light through two polarizers arranged with axes at angles to each other, from 0° to 90°.

at a beam of light and that we can conceive it as a bundle of rapidly vibrating arrows pointing outward in an infinite number of directions (Fig. 40a). A polarizing filter can cause all vibrations to take place parallel to each other (Fig. 40b).

The polarizer transmits not only the vibrations which are originally parallel to the polarization axis, but all the components of all the infinite number of vibrations at angles to the axis. The amplitude of any vibration along the axis is equal to

$$A_1 \cos \alpha$$

where α is the angle between the direction of vibration and the axis (Fig. 41).

Since the energy of a vibration is proportional to the square of its amplitude, the relative intensity I_u of light transmitted by two polarizers with axes at any angle from 0° to 90° is given by

$$I_u = I_o \cos^2 \alpha$$

when the angle between the polarizing axis is α and I_o is the relative intensity of the transmitted light when the angle α is zero.

A graphical representation of this, with I_o arbitrarily equal to unity, shows the relative intensity of the light through two polarizers with axes at various angles to each other (Fig. 42). This curve is true only for perfect polarizers which would have a transmission of 50%. Actually, the best polarizers have a transmission of only about 40%.

Conclusion

The fundamental requirement of any stereoscopic system is that each eye sees only that member of the stereoscopic pair intended for it and excludes the image belonging to the other eye. The disparate images of the stereoscopic pair must be distributed to the eyes of the audience in a selective manner. To quote from Dr. H. E. Ives:

"There are only two places where the distribution of images to eyes can be done; these are at the screen and at the eyes. The number of images at the screen can be reduced to two, if the number of viewing instruments is equal to the number of spectators. The number of viewing instruments can be reduced to zero if the number of images at the screen is made infinite. Any gain in simplification at one point is offset by increase in the complexity or expense at the other."

Editor's Note

When this paper was reviewed for reprinting, it was approved by the Board of Editors, with two recommendations: (1) that the illustrations be given numbers and referred to in the text; and (2) that references be prepared, keyed to the respective portions of Mr. Norling's text.

Except for the man with the derby and stereo camera (omitted in this reprint of the original), the illustrations were easily enough numbered; but to prepare and key a reference list was more than could be done in the time available, so the following bibliography is presented. It is not a complete bibliography nor is it even necessarily a complete guide to all the details and bases behind Mr. Norling's reporting. This bibliography is offered for what it is worth in relation to this article.

A more comprehensive bibliography on stereoscopic and wide-screen motion pictures is expected soon from the Society's Stereoscopic Motion Pictures Committee.

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Reels, Magazines, Spindles for 3-D

For theater owners who are planning to equip for 3-D, the present magazine-reel-spindle situation is chaotic, to say the least. It may therefore, serve a useful purpose to discuss a number of factors related to the current problem, as viewed by the engineers, and to report on efforts now being made to smooth the path toward conversion.

Reel Size

The vast majority of theaters have only two or at best three projectors, and since 3-D today requires simultaneous use of two machines, the "continuous performance" goes out. The length of an "average" motion picture program, including feature and some combination of abbreviated second feature, newsreel or short subjects, will run about two hours, as a conservative estimate, and at the standard projection rate of 90 ft/min, will use 90 × 60 × 2 or 10,800 ft of film. As it is physically impractical to put two miles of film on a single reel, theaters must use more than one reel per program. Most will need one or more intermissions to permit rethreading the two projectors; the minimum is obviously preferred.

Reel size is not critical if more than one intermission is planned (although a standard will be necessary). Considering the single intermission, therefore, it would appear that a reel should have a minimum capacity of 5400 ft. Assuming a hub diameter of 5 in. (presently contemplated), it has been estimated by the Motion Picture Research Council and others that this footage does require a *24-in. diameter reel*. Exact determination will depend on such variables as take-up tension, thickness of film, condition and cleanliness of film, etc. It should be noted that a reel can hold roughly 10% more black-and-white than color film because of the difference in film thickness.

However, the only large reels now being produced in quantity, against orders from a large number of exhibitors, are 23 in. and not 24 in. The reasons for this are twofold: partly economic and partly based on the technical considerations of the early 3-D productions.

First: *Bwana Devil* totals 7600 ft and *House of Wax* reportedly will have a release footage of 8200 ft or approximately 10–15% less than the average 2-D and expected 3-D features. Capacity of the 23-in. reel is probably in the order of 4500–4800 ft. This capacity is therefore adequate for running one of these features plus a newsreel or short spliced to the end of reel two of the feature.

Second: At this critical moment of demand only 24-in. magazines and 23-in. reels are available. These were initially designed for some of the larger houses who wanted to decrease the number of changeovers and for the export market where the demand stemmed from single-projector theaters. To capitalize on the widespread initial interest in 3-D, the limited available stock was purchased and immediate orders placed for future delivery.

On the one hand, flexibility in film production and exhibition appear to call for a 24-in. reel and 25-in. magazine; on the other hand, immediate usefulness and availability of 23-in. reels and 24-in. magazines dominate the scene for the moment.

Magazines

Some exhibitors have voiced concern as to the possibility of installing the 24-in. or 25-in. magazines on their equipment. This has been with particular reference to theaters still using Universal bases. There is definite information that either modification can be made with but few exceptions. The exceptions occur where the Universal base is used in very cramped quarters. In those cases smaller magazines will have to be used and the number of intermissions increased.

Spindle Size

Diameter of the spindle in present use with 2000-ft reels is $\frac{5}{16}$ in. With the load increased some 250% by the larger reels of film, it is generally felt that the spindle diameter must be increased to withstand the increased stress. No definite recommendations have been made as yet although $\frac{1}{2}$ in. has been mentioned as a likely value.

Take-up Tension

With regard to the 24-in. reel, the MPRC has stated that "Because of their size and weight, such reels must have free wheeling flanges to minimize strain on the film when the machine is started." By making the flanges free-wheeling, the reel inertia is appreciably decreased. And, of course, it is the flywheel effect of the flange mass which produces the film damage; that is, the reel tends to stay at rest after the projector is started and to continue at a fixed speed once it is in motion. Therefore, with fast start projectors, slack is created at the start and when the reel catches up it tends to maintain its speed and consequently gives an awful wallop to the film perforations engaged in the hold-back sprocket.

Essentially what is required is a method of applying an adequate and constant take-up tension from the beginning of the start-cycle through to the end of the reel. Several methods, other than the free-wheeling reel, have been mentioned as potential solutions: use of a separate-drive, constant-torque motor, the double-cone type of mechanism and others.

Committee Meeting

The Film Projection Practice Committee has scheduled a meeting to consider those aspects of these questions which lend themselves to and require standardization. This will be reported in the next *Journal*.—*Henry Kogel*, Staff Engineer.

73d Convention, Los Angeles Statler, April 27 – May 1

Stereoscopic motion pictures and the engineering of drive-in theaters are phases receiving special attention at the Spring Convention. The technical and entertainment program is outlined on cards mailed on March 2 to all members in the western hemisphere. This card and the Advance Program, to be mailed March 27 to all members, will be sent to anyone on request.

President Herbert Barnett has announced plans for the Get-Together Luncheon:

Mitchell Wolfson, noted exhibitor, television broadcaster and former President of Theatre Owners of America, will speak at the opening luncheon, Monday noon. His keynote address will bring to Hollywood and to the engineers, the exhibitors' views on stereoscopic and wide-screen motion pictures, present outlook for theater television, and current prospects, technical and economic, for the drive-in theaters of the United States.

The Advance Program will give the full schedule, with abstracts, of the papers that Chairman Ralph Lovell now has firmly committed.

Stereo is scheduled for Monday afternoon and evening and Tuesday afternoon. Stereoscopic and wide-screen principles will be presented, along with photography and exhibition demonstrations. A stereophonic sound demonstration has been planned for Friday evening.

Television begins on Tuesday with a papers session and a tour of the new CBS Television City. Tuesday evening's session will have a progress report on NTSC color standardization. (The April *Journal* will have the popular paper on this subject presented at the Washington Convention by A. V. Loughren.) Subscription television will also be on the program. The television sessions have been scheduled to precede the NARTB engineering sessions which begin on April 29.

On Wednesday morning and afternoon it is drive-in theaters — factors affecting picture and sound quality and new equipment.

High-speed photographers take a trip on Wednesday to the U.S. Naval Ordnance Test Station's Morris Dam Test Facility at Azusa, Calif. High-speed papers are scheduled for Thursday evening and Friday morning.

Wednesday evening is set aside for the traditional Cocktail Hour and the Semi-annual Banquet and Dance.

And the morning after the ball — it's open house at the Hollywood film processing laboratories. Thursday afternoon offers film processing subjects and Thursday night, a general session. Friday's sessions are on sound recording and on magnetic

striping and editing. (All the Washington Convention magnetic striping symposium papers are to be published as Part II of the April *Journal*.)

There are now ten committee meetings and five committee reports scheduled during the week.

The Ladies Program is highlighted by an outdoor luncheon by the Huntington Hotel pool and tour of the Huntington Library in Pasadena, on Tuesday. A luncheon and tour of a motion picture studio are planned for Thursday and a luncheon on Wednesday at the Statler will precede a fashion show in the Terrace Room. Tickets for outstanding television and radio shows will be available at other times to help complete an active and interesting week.

There will be an equipment exhibit arranged particularly for new equipment described in papers on the technical program. Questionnaire forms are due by April 1 to Thomas J. Gibbons, Exhibit Chairman, 446 N. La Brea Ave., Hollywood 36, Calif.

Opening of the Registration Desk has been moved up to Sunday afternoon by Convention Vice-President Jack Servies and Local Arrangements Chairman Vaughn Shaner. The people now making the plans and who will carry the Convention through are:

Program Chairman — Ralph E. Lovell
Papers Committee — Chairman, W. H. Rivers — Vice-Chairmen, J. E. Aiken, Skipwith W. Athey, Geo. W. Colburn, G. G. Graham, John H. Waddell
73d Convention High-Speed Photography — Carlos H. Elmer
Local Arrangements — Vaughn C. Shaner
Banquet — Sidney P. Solow
Door Attendants — USC Student Chapter
Exhibits — Thomas J. Gibbons
Hotel Reservations and Transportation — Philip G. Caldwell
Luncheon — Loren L. Ryder
Membership and Subscriptions — John W. Duvall
Motion Pictures — Ted Fogelman
Projection, 35mm and 16mm — Chairman, M. B. Smith, assisted by Merle Chamberlin and Allan C. Curtis
Public Address and Recording — Edwin W. Templin
Publicity — Harold Desfor
Registration and Information — Robert Young
Ladies Reception and Registration — Mrs. Vaughn C. Shaner

The Seventy-Fifth Semiannual Convention

A year from now the Society will hold its seventy-fifth semiannual convention. The event will be marked by emphasis on the historical aspect of the development of motion picture engineering.

During the Chicago Convention last year plans were initiated and John Frayne accepted the Chairmanship of a special committee formed to accomplish a special program which will include authoritative historical papers outlining the development of the cinematographic arts and associated technologies. The Committee is also working on the selection of pioneers who will be properly honored at this Convention for their contribution to the industry.

The roster of the Committee is:

John G. Frayne, *Chairman*
Edmund A. Bertram
Frank E. Cahill
James Card
John I. Crabtree
James W. Cummings
Emery Huse
Axel G. Jensen
Barton Kreuzer
J. B. McCullough
Peter Mole
H. W. Moyse
Terry Ramsaye
E. I. Sponable

The Historical and Museum Committee, under Chairman John B. McCullough, will contribute substantially to the 75th Convention Program.

Suggestions or proposals for any aspects of the 75th Convention will be welcomed by John G. Frayne, 6601 Romaine St., Los Angeles 38, Calif.—*V.A.*

1953 Nominations

The Nominating Committee under the Chairmanship of Peter Mole, 941 North Sycamore Ave., Hollywood 38, Calif., is now considering candidates for election to national offices of the Society. The Chairman invites all Fellows and Honorary and Active Members to submit their suggestions. At the end of 1953 nine vacancies are to occur — they will be in the offices of Engineering Vice-President, Financial Vice-President and Treasurer and the following Governorships: two from the East, two from the Central area and two from the West. Incumbents are listed on the inside back cover of each *Journal*.

Mr. Mole requests that suggestions be sent to him at the earliest possible date because the Committee has a substantial amount of work to be accomplished as is specified in Bylaw VIII which appeared last on page 345 of the *Journal* for April 1952.

Pacific Coast Section Meeting

The February Pacific Coast Section meeting with a program entitled "Three-Dimensional Motion Pictures" brought out an unprecedented attendance of 800. It was originally intended to open the meeting to all interested motion picture and television engineers, but the response to the first notice was so great that follow-up notices had to be sent advising that admittance would be restricted to members of the SMPTE plus members of the Hollywood Section of the American Society of Cinematographers.

The program, held on the sound stages at the Republic Picture Studios, presented speakers from the 3-D field and short film demonstrations. Sol Lesser Productions provided a Stableford screen from England. Members examined it and asked questions about it following the meeting. Mr. Lesser very kindly provided the Polaroid glasses for viewing the films.

Dr. Harold R. Lutes, President of the H-L Instrument Company, and a manufacturer and developer of optical instruments and photographic equipment, spoke briefly on some of the psychological problems encountered in stereoscopic photography and illustrated his discussion with a series of slides designed to show the optical illusions and depth perception sensations possible with three-dimensional photography.

Raymond J. Spottiswoode, Technical Director of Stereo Techniques, Ltd., London, spoke on "Practical Aspects of Three-Dimensional Motion Picture Photography," and showed three of Stereo Techniques' films, one an animated production. Mr. Spottiswoode's discussion was of great interest to the group, very well presented and greatly heightened by a charming sense of humor and understanding of his audience.

Raphael G. Wolff, President of Raphael G. Wolff Studio and Stereo-Cine, Inc., offered film demonstrations from current productions to illustrate some of the results available today to the professional motion picture producer or commercial film producer through the use of stereo photography.—*Philip G. Caldwell*, Secretary-Treasurer, Pacific Coast Section.

SMPTE Lapel Pins are available from the Society's headquarters. They are gold and blue enamel, with a screw back. The pin is a ½-in. reproduction of the Society symbol — the film, sprocket and television tube — which appears on the *Journal* cover. The price of the pin is $4.00, including Federal Tax; in New York City, add 3% sales tax.

Book Reviews

Filter Design Data for Communication Engineers

By J. H. Mole. Published (1952) by John Wiley, 440 Fourth Ave., New York 16. i-xvi + 246 pp. + 4 pp. index. 127 illus. 56 tables. 6 × 9¼ in. Price $7.50.

This volume, as its title indicates, is primarily intended for the engineer concerned with filter design. Emphasis is on design problems to the almost complete exclusion of theoretical considerations. Derivations of formulas have been included only when necessary to the clarity of presentation. All filters treated are, with one exception, Zobel filters. This exception is the coupled resonant bandpass filter. An elementary knowledge of transmission and filter theory has been assumed. For a person with such a background, the explanation of design methods is adequate.

The author has succeeded in presenting a large amount of design data in this 252-page volume. More than 70 of the 127 figures are charts directly concerned with numerical evaluation. Design data for a large number of specific filter configurations (in excess of 30) is presented. These vary from a single section to a filter of five M-derived sections (with different M values) plus a terminating k section. Sufficient data are presented to enable one to determine the minimum number of elements required for the solution of a given design problem and to assign element values after having determined the required configuration.

Included is a chapter on the determination of tolerances required on individual elements to meet a specified overall tolerance. This problem is approached by the theory of probability.—*G. W. Read*, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

Comptes rendu Proceedings of 1951 Stockholm Convention of the Commission Internationale De L'Éclairage

Published (1952) by the Central Bureau of the Commission Internationale De L'Éclairage. 1706 pp. Available at a delivered price of $12.50 per set of 3 vols., from T. D. Wakefield, Treasurer U.S.N.C., I.C.I., F. W. Wakefield Co., Vermilion, Ohio.

The twelfth session of the International Commission on Illumination was held in Stockholm, Sweden, in June and July, 1951. The proceedings are published in three volumes described as follows:

Volume I contains the Secretariat Reports for the separate committees participating. The twenty-odd contributing committees cover such subjects as definitions and units, methods of measurement, physiology and theories of vision, light sources and all sorts of practical applications of lighting. The Secretariat Reports contain much material contributed from many different countries which should be of great value to any student or research worker interested in the subjects covered; for, in many instances, they contain very extensive bibliographies consisting of literally hundreds of references to papers from many lands. The report of Committee 62d on Cinema Lighting contains information submitted by members from Belgium, Czechoslovakia, Denmark, France, Great Britain, Norway, Sweden and the U.S.A. It is gratifying to note that so many countries by independent means have arrived at *approximately* the same range of recommended screen brightness as our own for viewing 35mm motion pictures.

Volume II contains forty-five papers on a wide range of subjects presented at the Stockholm Meeting by individual delegates.

SMPTE Officers and Committees: A new publishing of the roster of Society Officers and the Committee Chairmen and Members is scheduled for the April *Journal*. The last one is in April 1952.

Volume III contains a complete list of the delegates and visitors, minutes of the meetings, and the official recommendations of the C. I. E. Many of the recommendations of committees of the C. I. E. have already been published in various journals. Some were contained on pages 734–738 of the *Journal of the Optical Society of America*, Vol. 41, Oct. 1951. Recommendations by Committee 62d on Screen Lighting in Cinemas and those of Committee 63 on Television were reported on pages 283 and 284 of this Society's *Journal* for September 1951. The minutes also report the change of name of the Commission from International Commission on Illumination (I. C. I.) to Commission Internationale De L'Éclairage (C. I. E.) because of a conflict with the prior trademark of Imperial Chemical Industries in England.

Decision was announced to hold the next meeting in 1955 in Switzerland.—*W. W. Lozier*, National Carbon Co., Fostoria, Ohio.

A Television Policy for Education

Carrol V. Newsom, Editor. Published (1952) by American Council on Education, 1785 Massachusetts Ave., N.W., Washington 6, D.C. i-xx + 267 pp. 6 × 9 in. Price $3.50.

Engineers, industrialists, administrators from government and education, lawyers, entertainers, producers and other leaders related their experiences and aspirations in developing, administering and programming educational television at the Television Programs Institute held at Pennsylvania State College, April 20–24, 1952. Their papers have been abstracted in this well-edited volume, which includes a wealth of data on costs and practical steps to be taken.

The Institute was sponsored by the American Council on Education which is a council of national educational associations, universities, colleges, technological schools, state departments of education, and many other interested organizations including large public libraries.

The Institute meeting was a serious task project with the following Advisory Committee:

Milton S. Eisenhower, *Chairman;* President, Pennsylvania State College.
Arthur S. Adams, President, American Council on Education
Reverend Theodore M. Hesburgh, President, University of Notre Dame
Armand L. Hunter, Director of Television Development, Michigan State College
Francis Keppel, Dean, Harvard Graduate School of Education
George E. Probst, Director of Radio, University of Chicago
Mark C. Schinnerer, Superintendent of Schools, Cleveland
Ralph Steetle, Executive Director, Joint Committee on Educational Television

The staff for the Institute was:

Director: Carrol V. Newsom, Associate Commissioner for Higher Education, State of New York
Assistant Director: E. Arthur Hungerford, General Precision Laboratory, Pleasantville, N.Y.
Consultant to the Director: Frederick W. Hoeing, New York
Administrative Assistant: Mrs. Eunice Collins Parker, American Council on Education, Washington, D.C.

From these and some 90 other participants there has been derived for this volume a substantial presentation of addresses, panel discussions, reports and working papers. At the Institute there were 11 demonstrations which this book could only cite.

Parts of the information here will not be new to some engineers and their communities — but recent reports on experience in New York state bear witness that a little more thorough dissemination may not be a dangerous thing. The State's Temporary Commission on the Use of Television for Educational Purposes recently delivered a report that the *New York Times* on March 1, 1953, called "an incredibly clumsy and shocking document." The *Times* thoroughly followed out its headline: "Incredible Document — Report on Educational Video Is Shameful."

The worth of a book like *A Television Policy for Education* may be further assessed by noting from the March 8, 1953, *New York Herald-Tribune* the concluding paragraph which columnist John Crosby wrote

after supplying some of the known television cost figures:

"The worst effects of the commission report are psychological. New York State has always been considered a leader in affairs of this sort. Other legislatures and even private educators who had been interested in educational TV might assume that New York has examined the thing honestly and found it wanting. This is untrue. Gov. Dewey has long been hostile to the Board of Regents and to everything they propose. The commission seems to have fallen all over itself to accommodate him, even to the extent of falsifying every known fact about educational television."—*V.A.*

Audio-Visual Communication Review

This is a new quarterly issuing from the Department of Audio-Visual Instruction (DAVI) of the National Education Association, 1201 16th St., N.W., Washington 6, D.C. Articles deal mostly with film and television from a cultural point of view, and a department of "Research Abstracts" provides précis of articles from other publications, dealing with films and television as training media.

Journals Available and Wanted

These notices are published as a service to expedite disposal and acquisition of out-of-print *Journals*. Please write direct to the persons and addresses listed.

Available

5 years (1947–51) in perfect condition plus the indexes for 1936–45 and 1946–50 and including the 1949 High-Speed Photography, upon any reasonable offer to Vic Gretzinger, 3547 Suter St., Oakland 19, Calif.

1951–1952 Journals in excellent condition plus the Indexes for 1916–30, 1930–35, 1936–45 and 1946–50; and including the 1949 High-Speed Photography. Write to K. C. Tsien, 147–51 Charter Road, Jamaica 35, N.Y.

Wanted

Transactions 1, 6 and 7. Write Mrs. Dorothy Gelatt, Henry M. Lester, 101 Park Ave., New York 17, N.Y.

April, 1934; May, 1936; Jan., 1938; Apr., 1939; June, 1940; July, 1941; Feb., 1944; Jan. and Aug. 1945; Jan., Feb. and Mar. 1946; Jan., 1947; Jan. and Feb. 1948; Mar. (in 2 parts), July, Aug. and Sept. 1949 and Feb. 1950. Write to Mr. Ishan Ghosh, Chief Technician, Kardar Productions 30, Government Gate Rd., Parel, Bombay 12, India.

January and February 1946 *Journals*. Advise the Record Engineering Library, Radio Corporation of America, RCA Victor Division, 501 N. LaSalle St., Indianapolis, Ind.

Sets of 74 standards (with index) in heavy three-post binders are available at $15.00 (plus 3% sales tax on deliveries within New York City). Foreign postage is $0.50 extra. These sets include the latest standards approved: PH 22.1-1953, PH 22.84-1953, PH 22.85-1953 and PH 22.92-1953.

If all present owners of binders will communicate with the Society, these four new standards will be sent to them gratis.

Single copies of any particular standard must be ordered from the American Standards Association, 70 East 45th St., New York 17, N.Y. Only complete sets are available from Society headquarters.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Bird, Herbert Leslie, Chief Sound Engineer, UNESCO Mission, c/o Israel Motion Picture Studios, Ltd., Herzliya, Israel. (A)

Brooks, Walter H., Editor, Managers' Round Table, Motion Picture Herald, 1270 Sixth Ave., New York, N.Y. (A)

Byars, Taylor, Motion Picture Cameraman, Technical Director, Five Star Productions. **Mail:** 623 N. Lamer St., Burbank, Calif. (M)

Harburger, Albert N., Film Editor and Producer, 630 Ninth Ave., New York 36, N.Y. (M)

Hartzband, Morris, Free-lance Cameraman. **Mail:** 99-45 67 Rd., Forest Hills, N.Y. (A)

Herman, Frank J., Processing Foreman, Geo. W. Colburn Laboratory, Inc. **Mail:** 7950 Drexel Ave., Chicago, Ill. (A)

Killough, John G., Film Technician, Printer Foreman, Acme Film Laboratory. **Mail:** 1444 Miller Dr., Los Angeles 46, Calif. (M)

Kiteley, Raymond C., Motion Picture Cameraman, AF 11233560, Hq. Sq. Sec. Air Force Flight Test Center, Edwards Air Force Base, Calif. (A)

Maguire, Frank J., Assistant Director, Medical Films, Audio Productions, 630 Ninth Ave., New York, N.Y. (A)

Morse, Leonard P., Photographer, Visual Aids Technician, Pratt & Whitney Aircraft. **Mail:** 10 Dorothy St., Hartford 6, Conn. (A)

Postal, Julius Bernard, Technical writer, Avion Instrument Corp. **Mail:** 435 Warwick St., Brooklyn 7, N.Y. (M)

Robins, Ben W., Manager, Sound and Visual Design Group, RCA Victor Division. **Mail:** Haddon Hills Apt. 217-D, Haddonfield, N.J. (M)

Schmit, Joseph W., Chemical Engineer, Technicolor Motion Picture Corp., 6311 Romaine, Hollywood 38, Calif. (A)

Smith, Warren R., Motion Picture Technician, Warren R. Smith, Inc. **Mail:** 2560 Monroeville, Rd., Turtle Creek, Pa. (M)

Sobin, Ben, Visual Education Service, Boy Scouts of America, 2 Park Ave., New York, N.Y. (A)

Valenzio, Victor E., Motion Picture Cameraman, U.S. Signal Corps Pictorial Center. **Mail:** 101-64 105 St., Ozone Park 16, N.Y. (A)

Vanderhoek, E. F., Manager, Westrex Corp. (South-East Asia), 138 Robinson Rd., Singapore, Malaya. (M)

Williams, J. Gordon, Transmission Engineer, Sound Services, Inc. **Mail:** 404 W. Valencia Ave., Burbank, Calif. (A)

Zucker, Burton H., Assistant Cameraman, Camera Equipment Co., 1600 Broadway, New York, N.Y. (A)

CHANGES IN GRADE

Boden, William F., (S) to (A)
Howard, William A., (A) to (M)
Ushijima, Henry, (A) to (M)

DECEASED

Heacock, Frank C., Office Manager, Eastern Columbia. **Mail:** Box 136, San Gabriel, Calif. (A)

Poulsen, Arnold, Director, Electrical Fono-Films Co., Meldahlsgade 5, Vesterport 1523, Copenhagen, Denmark. (A)

Sherman, Harry, Labor Editor, International Projectionist Publishing Co., 19 W. 44 St., New York 18, N.Y. (M)

Meetings

Society of Motion Picture and Television Engineers, Central Section Meeting, Apr. 16, Encyclopaedia Britannica Film Studios, Chicago

Symposium on Modern Network Synthesis, planned by Polytechnic Institute of Brooklyn, Apr. 16–18, Auditorium of Engineering Societies Bldg., New York

International Symposium on Nonlinear Circuit Analysis, Apr. 23–24, information from Microwave Research Inst., 55 Johnson St., Brooklyn 1, N.Y.

73d Semiannual Convention of the SMPTE, Apr. 27–May 1, Hotel Statler, Los Angeles

National Association of Radio and Television Broadcasters, 7th Annual Conf., Apr. 28–May 1, Ambassador Hotel, Los Angeles

American Physical Society, Apr. 30–May 2, Washington, D.C.
Acoustical Society of America, May 7–9, Hotel Warwick, Philadelphia, Pa.
Society of Motion Picture and Television Engineers, Central Section Meeting, May 14, (tentative), Western Society of Engineers, Chicago
Society of Motion Picture and Television Engineers, Southwest Subsection, May 20, Dallas, Tex.
Society of Photographic Engineers, Third Annual Conference on Science in Photography and Photographic Instrumentation, May 20–22, U.S. Hotel Thayer, West Point, N.Y.
Society of Motion Picture and Television Engineers, Central Section Meeting, June 11, Geo. W. Colburn Laboratory, Chicago
American Physical Society, June 18–20, Rochester, N.Y.
American Institute of Electrical Engineers, Summer General Meeting, June 29–July 3, Atlantic City, N.J.
Biological Photographic Association, 23d Annual Meeting, Aug. 31–Sept. 3, Hotel Statler, Los Angeles, Calif.
The Royal Photographic Society's Centenary, International Conference on the Science and Applications of Photography, Sept. 19–25, London, England
National Electronics Conference, 9th Annual Conference, Sept. 28–30, Hotel Sherman, Chicago
74th Semiannual Convention of the SMPTE, Oct. 4–9, Hotel Statler, New York
Audio Engineering Society, Fifth Annual Convention, Oct. 14–17, Hotel New Yorker, New York, N.Y.
Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31–Nov. 4, Conrad Hilton Hotel, Chicago, Ill.
Theatre Owners of America, Annual Convention and Trade Show, Nov. 1–5, Chicago, Ill.
National Electrical Manufacturers Association, Nov. 9–12, Haddon Hall Hotel, Atlantic City, N.J.
75th Semiannual Convention of the SMPTE, May 3–7, 1954 (next year), Hotel Statler, Washington, D.C.
76th Semiannual Convention of the SMPTE, Oct. 18–20, 1954 (next year), Ambassador Hotel, Los Angeles

Employment Service

Positions Available

Wanted: Cameraman-Director, young man free to travel, to work in Southern states. Must be able to show sample footage. Send résumé of experience and personal details in letter. Address replies to P.O. Box 1531, Louisville, Ky.

Career Opportunity in Midwest: for competent photographer and cinematographer experienced in 16mm production techniques to become permanently associated, as working partner, with well established, financially responsible company producing medical and scientific films exclusively. Must be under 40, of excellent character, good personality and educational background. Write, stating age, education, experience, history of employment, marital status, salary expected and where confidential correspondence can be addressed.—Mervin W. LaRue, Inc., 159 E. Chicago Ave., Chicago 11, Ill.

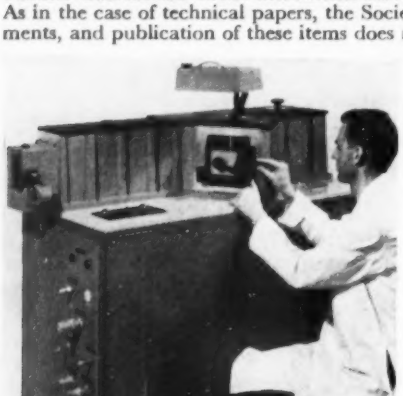
Permanent Position in Southwest for experienced motion picture cameraman; must have sample interior and exterior footage to indicate ability. Write letter, giving résumé of professional experience, to Susong Agency, 524 Commercial Bldg., Dallas, Tex.

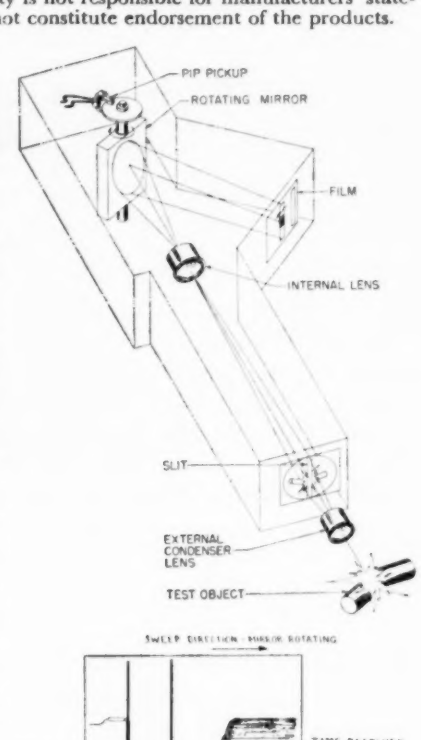
Position Wanted

Resigned Feb. 1 as gen. mgr., charge of production, large southern film studio. 15 yrs. experience as prod. mgr., editor and cameraman, 16mm and 35mm. Married, 37, college grad. References and résumé on request — Harlan H. Mendenhall, 5141 Bataan St., Houston, Tex.

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.





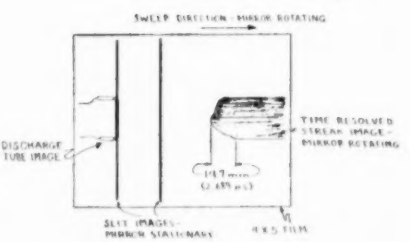
This is a new research camera, Model 168, developed by Beckman and Whitley, Inc., San Carlos, Calif., and described here with data supplied by Jack Chambers, Director of Research of that organization.

This smear or streak type of camera images the event to be studied through the vertical slit at the upper left, then the rotating stainless-steel mirror wipes the image onto film at a sweep rate of 0.327 to 5.466 mm/μsec. Either 4 × 5 in. or 4 × 10 in. film is used. Inside the upper right section of the housing below the vertically projecting knob is the mirror which by the knob is secured in a vacuum-tight round access panel.

The schematic shows how a self-luminous image is projected through the slit by an external condenser lens which is not part of the instrument. The internal lens forms an inverted nonmagnified image of the slit in the film plane after reflection from the mirror surface.

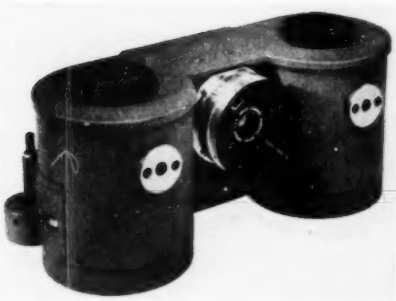
The slit width is 0.010 in. The slit plate is a piece of flat glass with an opaque coating on one side through which the slit line has been ruled. The shutter is a guillotine type to work at high speed to prevent multiple exposures, with exposure time of 1/200 sec. The mirror has a $3\frac{3}{4}$ × 4 in. reflecting surface. Temperature-monitoring thermocouples are mounted on the outer races of upper and lower mirror bearings.

As shown in the schematic, synchronizing of the exposure with actuation of the test object is accomplished through the pip-generating commutator seen on top of the mirror. Each turn of the mirror produces a 15-v minimum pulse


SWEEP DIRECTION - MIRROR ROTATING
DISCHARGE TUBE IMAGE
TIME RESOLVED STREAK IMAGE - MIRROR ROTATING
SLIT IMAGES - MIRROR STATIONARY
4 X 5 FILM

which is used to trigger and synchronize the test object so that the image will be positioned on the film.

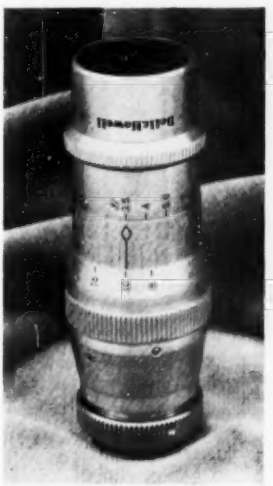
A typical recording is depicted in the last illustration. At the extreme left is a slit image photographed for the purpose of determining the position of the test object, a gas-filled glow-discharge tube. To the right is a second slit image also made with the mirror stationary. This image constitutes the time base from which measurements are made to the streak image at the extreme right. This image is produced with the mirror spinning and a synchronized high-voltage pulse applied to the tube.



The Auto Camera Mark 3 has been announced as available from J. A. Maurer, Inc., Photographic Instrumentation Div., 37–01 — 31st St., Long Island City 1, N.Y. Designed as a low-cost, lightweight, compact recording camera, it was originally provided for aircraft use by D. Shackman & Sons Ltd., London, England. It is $8\frac{7}{8}$ in. long, $3\frac{3}{8}$ in. wide, 4 in. high and weighs 6 lb. A spring motor drives the camera to transport and expose 21 ft of 35 mm film, the cycle being initiated by either a 12- or 24-v d-c pulse. The film is held in special cassettes. Five shutter speeds, from 1/10 to 1/200 sec, and "time" exposure, are provided. The standard lens supplied is a 36-mm focal length, *f*/3.5 in a graduated focusing mount. Other lenses are available and special models of the camera incorporate 6- or 9-in. lenses.

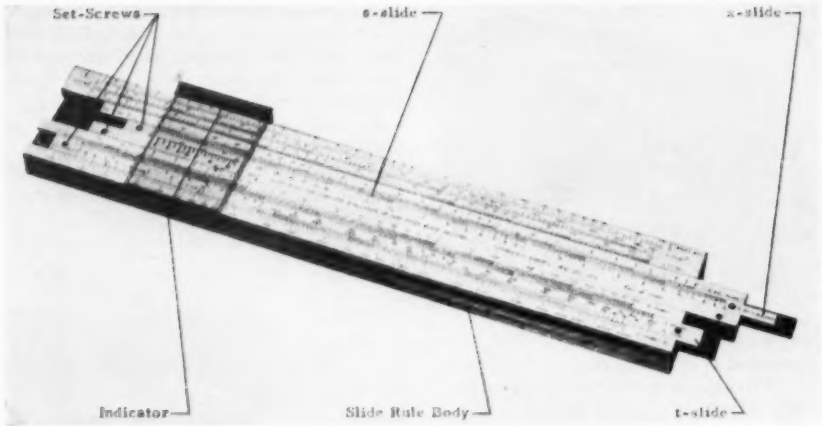
There are two models to provide alternatives of 200 pictures 1 in. × 1 in. or 300 pictures $\frac{3}{4}$ in. × 1 in. Accessories permit time-lapse recording, photomicrography, normal and stereo photomacrography, aircraft instrument and chemical experiment recording.

One-hundred and seventy-five television stations authorized to start operations during 1953 are listed in the 16th edition of Television Factbook, published by Television Digest, Wyatt Bldg., Washington, D.C. This figure covers all the post-freeze new television stations authorized through Jan. 3, 1953; of the 175, 48 are VHF and 127 UHF. *Television Factbook*, a semiannual reference guide, has 268 pages in the new edition and costs $3.00. A new feature in this issue is a group of directories of community antenna systems, theater-television installations, and FCC channel allocation tables with priority lists. Also included are revised and brought-up-to-date directories of: engineers and attorneys; manufacturers of television equipment, including receivers, transmitters, tubes, theater-television, and community antennas; program sources; FCC personnel; station representatives; trade associations; unions; and publications.



A new 3-in. *f*/3.5 telephoto lens for 16mm motion picture cameras has been announced by Bell & Howell Co., 7100 McCormick Rd., Chicago 45, Ill.

The new lens, which replaces the B & H 3-in. *f*/4 Telate lens, has all air-glass surfaces coated. Accuracy of focusing is secured by matching the lens and focusing scale within 1%. The lens carries an easy-to-read, standard spread-out iris scale with a range from *f*/3.5 to *f*/22. Click stops assure positive setting and prevent accidental changes of the diaphragm opening. The depth of field scale is filled in red for readier identification. Distances are calibrated in feet from film. Supplied with the lens are a metal lens cap and a sunshade. The sunshade serves also as a filter-holder. The retail price of the new lens, which is now available from Bell & Howell dealers, is $79.95. (Federal excise tax is not applicable.)



This is the first working model of the Revised Slide Rule for complete analysis of high-speed motion picture data.

In mechanics research, rapid methods for quantitative analysis of high-speed motion picture data are highly desirable. A first step in this direction was a slide rule developed at Springfield Armory in 1950, described before the Society at its 1951 Spring Convention and in a paper published in the June 1951 *Journal*. That model was essentially planned for determining the operation time and cyclic rate of moving parts, with additional use for some precalculation tasks.

Recently, a more general slide rule has been developed. It and some of its possibilities were described in detail before the Society at its 1952 Fall Convention. It has been designed to allow for determination of displacement, velocity and acceleration of moving parts. It consists of slide rule body, three slides and an indicator, and carries scales for camera speed. number of frames, time, length of film interval, cyclic rate, object displacement, image displacement, velocity, acceleration and depth factor. The proper setting of the three slides is determined by the camera speed, the magnification and the length of film interval selected. The indicator is used for aligning corresponding values in various scales, such as number of frames vs. time, object displacement vs. image displacement, displacement vs. velocity, and velocity change vs. acceleration. In addition, a data sheet has been developed to serve as a guide for the sequence of measuring and calculating operations and for plotting the results.

The slide rule and the data sheet have been used at Springfield Armory over a period of some months and have proved successful, with much time saved in calculations. A computing aid, after brief training, can perform the whole operation, and it appears that errors in numerical calculations are reduced. The slide rule is expected to be of special value to small installations where expensive computing equipment is not justified.

Manufacture and sale of the slide rule on a commercial basis have been postponed until the pending patent application is cleared. Further information is available from Springfield Armory, Atten: Karl W. Maier, Springfield 1, Mass.

A new edition of the Society's Test Film Catalog is now available at no charge from the Society's headquarters. It covers 27 different test films, 16mm and 35mm, for use by theaters, service shops, factories and television stations. These test films have been developed by the SMPTE and the Motion Picture Research Council.

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